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Scattering and Attenuation by Precipitation Particles

Carol A. Boudreau
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7	Perturbative Forces Affecting the Motion of Artificial Earth Satellites 1955-June 1961	AD 272 830	H-381	2 Oct 61
8	Artificial Intelligence – Soviet Bloc	AD 271 667	H-378	27 Dec 61
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14	Radar Astronomy 1946-Aug 1962	AD 294 683	H-462	31 Dec 62
15	Radomes. Part 1	AD 401 159	H-493	31 Jan 63
	Radomes. Part 2	AD 403 145	H-662	28 Feb 63
17	Diamond: Synthesis and Properties 1958-1962	AD 415 716	H-509	30 Apr 63

* Missing numbers represent unpublished bibliographies.

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SCATTERING AND ATTENUATION BY PRECIPITATION PARTICLES

CAROL A. BOUDREAU

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PREFACE

This bibliography is offered to encourage the further application of radar meteorological techniques and data in connection with the study of the effects of hydrometeors, precipitation, clouds and fog on microwave propagation. It combines material developed in regard to weather radar research with the more conventional works on attenuation. The evolution of quantitative measurements by radar of the spatial distribution of precipitation in the past ten years provides a substantial body of information useful in establishing propagation effects on space communications links operating at short wavelengths. In addition to the weather radar material, the bibliography includes references on thermal radiation from precipitation, cloud physics, and dielectric and scattering properties of hydrometeors. Some of the references are pertinent to the study of propagation at optical wavelengths and are useful in evaluating the performance of laser communications systems.

M. L. Stone

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

INTRODUCTION

This bibliography is the result of a survey of the literature published between January 1950 and October 1964 on "Microwave Attenuation by Precipitation." Research in this field began in the early part of the twentieth century. Although 1950 was chosen as the starting date for the search, pertinent references published previous to this date have been included.

The references are listed alphabetically by author. Technical reports, which have no particular authors, are entered by corporate author. A subject outline and index has been provided. The subject outline was modeled after the outlines used in the American Meteorological Society Weather Radar Bibliographies.

Appreciation is extended to Mrs. Grace E. Boyd, who searched the foreign literature, to the DDC request bibliographic service, and to the compilers of bibliographies and review articles on radar meteorology.

Sources Consulted

ASTIA Technical Abstract Bulletin	1953 - Oct 1964
Meteorological Abstracts and Bibliography	1950 - 1956
Meteorological and Geoastrophysical Abstracts and Bibliography	1957 - Aug 1964
Science Abstracts/Electrical Engineering	1950 - Oct 1964
Science Abstracts/Physics	1950 - Oct 1964
Technical Translations	1959 - Oct 1964
Translation Monthly	1955 - 1958
American Meteorological Association Translation List	
Associated Technical Services Translation List	
Atomic Energy Commission Translation Title List and Cross Reference Guide	
Canadian Translation List	
Lincoln Laboratory Library and Document Catalogs	
Massachusetts Institute of Technology Library Catalog	

SUBJECT OUTLINE AND INDEX

NOTE: 'L' appearing after a reference number indicates that the article contains information applicable to propagation at optical wavelengths.

SCATTERING AND ATTENUATION BY PRECIPITATION PARTICLES

1. Aden, A. L.

   Microwave Reflection from Water Spheres
   Am J Phys; Vol 19, No 3, p 163–167 (Mar 1951).

   > Laboratory experiments, significant for the investigation of microwave reflection from rain, are described. Thirty measurements of water in the critical electrical-size region are presented graphically.

2. Aden, A. L. and Kerker, M.

   Scattering of Electromagnetic Waves from Two Concentric Spheres
   J Appl Phys; Vol 22, No 10, p 1242 (Oct 1951).

3. Allaries, H.

   A 4 mm Radar Installation
   Phillips Tech Rev; Vol 25, No 10, p 274–286 (1963/1964).

   > A description of a radar set operating at 4 millimeters at the Phillips Research Laboratories in Eindhoven is given. The radar attenuation for various conditions of mist and rain are estimated. The loss in mist is largely attributed to scattering rather than absorption.

4. Anderson, L. J.

   Attenuation of Microwaves by Atmospheric Gases and by Rainfall
   Joint Commission on Radio-Meteorology International Council of Scientific Unions – 2nd Annual Meeting, Brussels (Aug 1951), p 70–73.

   > Light to moderate rain will reduce the maximum distance over which communication can be established on 1.25 cm to one-tenth its normal value.

5. Anderson, L. J.

   Drop-Size Distribution Measurements in Orographic Rainfall
   Bull Am Meteorol Soc; Vol 29, No 7, p 362–366 (Sep 1948).

6. Anderson, L. J., Day, J. P., Freres, C. H. and Stokes, A. P. D.

   Attenuation of 12.5 centimeter Radiation through Rain
   IRE Proc; Vol 35, No 4, p 351–354 (Apr 1947).

   > This experimental determination of attenuation of 12.5 centimeter radiation through rain gave a result of 0.37 decibels/mile/mm/hr. Drop size measurements were made. The experiment took place near Hilo, Hawaii.

7. Aoyagi, J.

   Areal Rainfall Amounts Obtained by a 3.2 cm Radar and a Raingage Network
   11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 116.

8. Asami, Y.

   Microwave Propagation in Snowy Districts
   Monogr Ser, No 6, Res. Inst. of Appl. Electron., Hokkaido Univ., Sapporo, Japan, 1958.

   > Presents a comprehensive treatment of microwave propagation in snowy districts including absorption, reflection from snow covered ground, ice and snow accretion on antennas. The dielectric properties of ice, snow, and supercooled water were investigated. Anti- and de-icing techniques for microwave antennas are described.

9. Atlas, D.

"Advances in Radar Meteorology"
Advances in Geophysics, Landsberg, H. E., Vol 10 p 317–478, Academic Press, New York, 1964.

Reviews the major developments in radar meteorology since 1957 with particular attention to "quantitative interpretation" of observations. A comprehensive bibliography is included.

10. Atlas, D.

Drop Size and Radar Structure of a Precipitation Streamer
J Meteorol; Vol 14, No 3, p 261–271 (Jun 1957).

A detailed analysis is presented of the structure of an isolated precipitation streamer and of its drop-size history observed at the ground. A discussion of the "bright band" theory of melting graupel is included.

11. Atlas, D.

Microwave Scattering from Non-Spherical Hydrometeors
2nd Weather Radar Conference, Urbana, Ill. (Oct 1951), Sponsor: Univ. of Ill.

12. Atlas, D.

Progress in Radar Meteorology and Cloud Physics
URSI XIVth General Assembly, Tokyo, Japan (Sep 1963), Sponsor: Nat. Acad. Sci. Nat. Res. Counc., p 244–245.

13. Atlas D.

Radar Analysis of Severe Storms
Am. Meteorol. Soc., Boston, Mass., 1963.

14. Atlas, D.

Scattering from Non-Spherical Hydrometeors
M.S. Thesis, Mass. Inst. of Tech., Cambridge, Mass., 1951.

15. Atlas, D. and Boucher, R. J.

The Relation of Cloud Reflectivity to Drop Size Distribution
3rd Weather Radar Conference, Montreal, Can. (Sep 1952), Sponsor: McGill Univ., p B–1 to B–8.

16. Atlas, D. and Chmela, A. C.

Physical-Synoptic Variations of Raindrop Size Parameters
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 21–29.

It is verified that the rain intensity corresponding to most size-spectra can be represented by a uniform collection of drops with size equal to the median volume diameter, D_0. This, and the strong preference for a particular distribution, permit development of a rainfall parameter diagram on which any two of the variables R – rain intensity, Z – reflectivity factor, W – water content, and D_0 fix the other two.

17. Atlas, D., Harper, W. G. and others

Radar Scatter by Large Hail
Imperial Coll. of Sci. and Tech., London, Ad-242 858, Tech Sci Note No 2, Contr AF 61(052)254 (Jan 1960).

Back-scatter cross-sections of artificial hailstones were measured at 3.3 and 4.67 cm. Ice spheres have cross-sections more than 10 times that of equal-sized water spheres when the diameter exceeds 1.2 wavelengths.

18. Atlas, D., Kerker, M. and Hitschfeld, W.

Scattering and Attenuation by Non-Spherical Atmospheric Particles
J Atmos Terr Phys; Vol 3, No 2, p 108 – 119 (Feb 1953).

19. Atlas, D. and Ludlam, F. H.

Multi-Wavelength Radar Reflectivity of Hailstorms
Quart J Roy Meteorol Soc; Vol 87, No 374, p 523 – 534 (Oct 1961).

20. Atlas, D. and Planck, V. G.

Atmospheric Attenuation of Short Microwaves
AFCRL Surv Geophys (Pt II); No 23 (1952).

21. Atlas, D. and Planck, V. G.

Drop-Size History during a Shower
J Meteorol; Vol 10, No 4, p 291-295 (Aug 1953).

Five drop-size spectra at 1-1/2 – 2 min intervals during shower at Watertown, Mass., shown by histograms, indicate a steady decrease of median volume diameter d_o from 1.8 to 0.3 mm. Distribution agrees with computed expression $d_o = 0.92\ R^{0.21}$, except for first drops, but reflectivity is only half that predicted by $Z = 200\ R^{1.6}$ (R, rate of rainfall).

22. Atlas, D. and Planck, V. G.

The Starting Transient of a Shower
3rd Weather Radar Conference, McGill Univ., Montreal, Can. (Sep 1952), Sponsor: McGill Univ., p D37 to D39.

A sequence of five closely spaced raindrop samples taken at the onset of a shower each displayed approximate monodisperisty and drops decreasing to drizzle size with time.

23. Atlas, D., Planck, V. G. and Paulsen, W. H.

Weather Effects on Radar
AFCRL Surv Geophys; No 23, p 43 – 53 (Dec 1952).

Atmospheric attenuation of the short microwaves in various conditions is reviewed along with many case histories.

24. Atlas, D. and Wexler, R.

Backscatter by Oblate Ice Spheroids
J Atmos Sci; Vol 20, No 1, p 48 – 61 (Jan 1963).

25. Atlas, D. and Wexler, R.

Radar Scatter by Large Non-Spherical Hail
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 218 – 224.

26. Austin, P. M.

Application of Weather Radar to Intensity of Surface Precipitation
Mass. Inst. of Tech., Cambridge, Mass., AD-439 855, Biannual Rep No 1, Contr DA 36 039AMCO2225E (Mar 1964).

Intensity levels on PPI and RHI, which depict the three dimensional distribution of precipitation, have been taken in 37 storms and cover 330 hours. In some of the storms data included radar-rain gauge comparisons, drop size samples, and radiosonde soundings. As part of the general numerical survey of storm structure, a special study on patterns has been initiated. It is based on 80 selected storms which clearly fall into one of three groups: lines, areas, miscellaneous.

27. Austin, P. M.

Distribution of Precipitation Echoes as Observed by Radar at Cambridge, Massachusetts
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 221–226.

A survey was made of the frequency of occurrence and distribution of echoes from precipitation within a range of 120 miles of Cambridge, Mass. Some results for 27 summer storms observed on the SCR-615-B and 38 on the AN/CPS-9 are presented here. The data have been analyzed to show the probability of detection of precipitation as a function of range and also to indicate local regions where precipitation occurs most persistently.

28. Austin, P. M.

Microstructure of Storms as Described by Quantitative Radar Data
Am Geophys Union, Geophys Monogr; No 5, p 86–93 (1960).

Instrumentation which has been developed recently presents radar echoes from precipitation in the form of range-corrected signal intensity contours, thus making it possible to observe in a quantitative manner the smaller-scale features within the precipitation areas which appear on the normal radar-scope presentation. This paper presents some preliminary results of the analysis of such data for two types of storms: warm-front type rain in an unstable atmosphere, and showers associated with instability lines. Dimensions, durations and motions of areas of heavy rain and of individual shower cells are considered.

29. Austin, P. M.

Observations of Attenuation of 3 cm Radiation by Precipitation
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 166.

30. Austin, P. M.

Radar Measurements of Precipitation Rate
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 120.

31. Austin, P. M.

Research Directed Toward the Investigation of Radar Techniques for Severe Storm Identification and the Measurement of Precipitation Growth
Mass. Inst. of Tech., Cambridge, Mass., AD-263 025, Final Rep 1 Jul 1957 – 30 Jun 1960, Contr AF 19(604)2291 (Aug 1961).

Quantitative data in the form of averaged, range-corrected iso-echo contours were obtained in many summer storms including twelve squall lines.

32. Austin, P. M.

Some Observations of Attenuation of 3.2 cm Radiation by Heavy Rain
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 325–330.

Comparison is made of the precipitation patterns presented by range-corrected signal intensity contours on the SCR-615-B radar (λ = 10.7 cm) and the AN/CPS-9 (λ = 3.2 cm) for a squall line and for a situation where general rain was occurring.

33. Austin, P. M. and Foster, H. E.

Note on Comparison of Liquid Water Content of Air with Radar Reflectivity
J Meteorol; Vol 7, No 2, p 160–161 (Apr 1950).

Radar reflectivity varies with type of precipitation as well as liquid water content. Measurements were made during 1947 – 1949 at Mass. Inst. of Tech.

34. Austin, P. M. and Geotis, S.

The Radar Equation Parameters
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 13–22.

An attempt has been made to assess the degree of accuracy obtainable with a radar used as a quantitative instrument. Types of measurements involved include beam patterns, standard targets and signal intensity over a rain gage.

35. AVCO Corp., Res. and Adv. Develop. Div.

Terminal Guidance System. Volume 3. The Effects of Weather and Ground Cover on the Performance of a Microwave Mapping Radiometer
AVCO Corp., Res. and Adv. Develop. Div., Wilmington, Mass., AD-445 635, Rep No TR62 8, Vol 3, Contr AF04 647 305 (Apr 1962).

The quantitative effects of weather and ground cover on the performance of a mapping radiometer operating at wavelengths of 0.86, 1.8 or 3 cm are considered, making use of microwave attenuation theory as applied to weather and basic electromagnetic theory.

36. Bader, H. and Kuroiwa, D.

Cold Regions Science and Engineering. Part II. Physical Science. Section B. The Physics and Mechanics of Snow as a Material.
Army Cold Regions Res. and Eng. Lab., Hanover, N.H., AD-287 052, Rep No 2-B (Jul 1962).

37. Banerjee, A. K., Sarkar, C. S. and Sen, S. R.

Unusual Spell of Late Night and Morning Fog at Agartala Airfield and Some Associated Features
Indian J Meteorol Geophys; Vol 14, No 1, p 50–52 (Jan 1963).

The diameter of fog particles was calculated from coronal measurements.

38. Barclay, P. A.

Study of Caboolture Storm, Comparison of Radar and Rain Gauge Observations
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 126.

39. Bartnoff, S.

Drop-Size Distribution and Visibility in Clouds and Rain
Tufts Coll., Dept. of Phys., Medford, Mass., Sci Rep No 1, Contr AF 19(604)-550 (May 1954).

The analysis of two sets of drop size distributions in natural clouds and one set of drop size distributions in rain indicates that the coefficient in Trabert's visibility equations, $V = (Cp\bar{r})/w$, is a function of the breadth of the distribution. In this equation, $\bar{r}$ is linear mean radius, p density, and w liquid water content. As pointed out by Atlas and Bartnoff, a more useful equation is found to be $V = (Kpd_o)/w$, where d_o is the median volume diameter.

40. Bartnoff, S.

Interpretative Techniques in Radar Meteorology
Tufts Coll., Res. Lab. of Phys. Electron., Medford, Mass., Final Rep, Contr AF 19(604)-550 (Jul 1955).

This report summarizes essential findings in studies on drop size distribution and visibility in clouds and precipitation, using Boucher's data obtained at Cambridge, aufm Kampe and Weickmann's 1950 data obtained in Cu clouds, and Diem's 1948 data. Studies on optical raindrop spectrometers and on scattering of electromagnetic radiation from a dielectric prolate spheroid are presented.

41. Bartnoff, S., Atlas, D. and Paulsen, W. H.

Experimental Statistics in Cloud and Rain Echoes
3rd Weather Radar Conference, Montreal, Can. (Sep 1952),
Sponsor: McGill Univ., p G1 to G7.

42. Bartnoff, S. and Atlas, D.

Microwave Determination of Particle-Size Distribution
Z Meteorol; Vol 8, p 130 – 131 (Apr 1951).

This is a preliminary note on the theory leading to research on the usefulness of microwave propagation methods for determination of the liquid water content of clouds and actual drop-size distribution in the cloud.

43. Barton, D. K.

"Survey of Propagation Effects"
Radar Systems Analysis, Chap 15, Prentice Hall,
Englewood Cliffs, N. J., 1964.

Presents basic engineering data on precipitation attenuation.

44. Barukova, Iu. A., Kamaldina, I. I. and Uchevatkina, T. S.

Amount and Intensity of Precipitation from Convective Clouds
TR G1 Geofiz Observ; No 104, p 14–24 (1960).

The method of calculating the growth of precipitation particles (raindrops and spherical hail), taking into account the working out of the cloud by precipitation, is presented.

45. Battan, L. J.

Radar Meteorology
Univ. of Chicago Press, Chicago, Ill., 1959.

A comprehensive treatment of radar meteorology providing a summary of all important works in the field through 1959 is presented.

46. Battan, L. J.

Relationship between Cloud Base and Initial Radar Echo
J Appl Meteorol; Vol 2, No 3, p 333–336 (Jun 1963).

The altitudes of the average initial precipitation echoes in convective clouds in Arizona for particular days have been compared with the altitudes of the calculated cloud base.

47. Battan, L. J.

Some Observations of Vertical Velocities and Precipitation Sizes in a Thunderstorm
J Appl Meteorol; Vol 3, No 4, p 415–420 (Aug 1964).

48. Battan, L. J. and Braham, R. R.

A Study of Convective Precipitation Based on Cloud and Radar Observations
J Meteorol; Vol 13, p 587–591 (Dec 1956).

Observations of precipitation and cloud-top height in the central United States and in the Caribbean area, obtained from radar-equipped airplanes, have been analyzed in terms of the fraction of clouds of a given height which contains precipitation.

49. Battan, L. J. and Herman, B. M.

The Radar Cross Sections of "Spongy" Ice Spheres
J Geophys Res; Vol 67, No 13, p 5139–5145 (Dec 1962).

50. Battan, L. J. and Reitan, C. H.

Conference on the Physics of Cloud and Precipitation Particles, Sep 1955, Proceedings
p 184–191, Pergamon Press, New York, 1957.

Curves showing mean droplet size distributions in fair weather cumuli and cumulus congestus clouds over the central U.S. and in tropical cumuli are presented. Droplet size distribution and liquid water content in fair weather cumuli are considered in some detail.

51. Baxter, D. C.

A Review of Radiation Scattering Methods for Measuring Cloud Droplet Size
Div. of Mech. Eng., Nat. Res. Counc., Ottawa, Can., AD-41 095, Rep No MD-40 (Apr 1954).

52. Bean, B. R.

"Attenuation of Radiowaves in the Troposphere"
Advances in Radio Research, Vol 1, p 121–156, Academic Press, New York, 1964.

Contains a review of material on attenuation and microwave radiation from precipitation.

53. Bean, B. R. and Riggs, L. P.

Attenuation of Microwaves
Nat. Bur. of Stand., Washington, D. C., AD-291 542, ESD TDR 62-290 (Oct 1962).

Analysis is devoted to a descriptive treatment of absorption of radio waves by raindrops and gaseous oxygen and water vapor in the atmosphere.

54. Bennett, L. and Stalder, J.

Drop Size Sensor
Rev Sci Instr; Vol 35, No 1, p 17–21 (Jan 1964).

A drop-size sensor capable of measuring the size and concentration of water droplets between 0.2 and 3 mm in diameter is described. The sensor is intended for balloon-borne measurements and radio transmission of solid and liquid precipitation particle data.

55. Bent, A. E.

Radar Detection of Precipitation
J Meteorol; Vol 3, No 3, p 78–84 (Sep 1946).

Presents illustrations of radar echoes from thunderstorms, showers, cold and warm fronts.

56. Bent, A. E.

Radar Echoes from Atmospheric Phenomena
Mass. Inst. of Tech., Radiat. La., Cambridge, Mass., Rep No 173 (Mar 1943).

Discusses various types of echoes. Describes and illustrates those related to meteorological phenomena.

57. Bentley, W. A.

Studies of Raindrops and Raindrop Phenomena
Monthly Weather Rev; Vol 32, p 450–456 (1904).

58. Berenbeim, D. Ia. and Kochkarev, G. N.

Unusual Hail
Meteorol Gidrol; No 7, p 41 (Jul 1958).

Showers fell from 11:08 o'clock to 12:35 o'clock and produced 35 mm of precipitation. The hail was associated with a cold front passage in the Kerch District.

59. Best, A. C.

The Evaporation of Raindrops
Quart J Roy Meteorol Soc; Vol 78, p 200–225 (Apr 1952).

The effect of evaporation upon the radar response from falling rain is examined.

60. Best, A. C.

The Size Distribution of Raindrops
Quart J Roy Meteorol Soc; Vol 76, No 327, p 16–36 (Jan 1950).

Using filter paper measurements at three stations in Britain and data by other workers, fraction F of liquid water in air, made up of drops of diameter less than x mm, is given by

$$1 - F = \exp[-(x/a)^n]$$

where $a = 1.30I^p$ (I = rate of rain in mm/hr); n is variable mean 2.25, maximum observed 6.1 in heavy showers. Weight W of water per unit volume of air = about $67I^{0.826}$.

61. Bibilashvili, N. Sh., Lapcheva, V. F., Ordzhonikidze, A. A. and Sulakvelidze, G. K.

Features of the Growth of Hail by Coagulation Related to the Variation of the Velocity of the Vertical Current at High Altitudes
Bull Acad Sci USSR, Geophys Ser; No 4, p 385–389 (1960).

62. Bigler, S. G. and Inman, R. L.

A Preliminary Classification of Radar Precipitation Echo Patterns Associated with Midwestern Tornadoes
Dept. of Oceanogr. and Meteorol., Tex. A & M Univ., College Station, Tex., Final Rep (Sep 1958).

63. Bigler, S. and Tarble, R. D.

Applications of Radar Weather Observations to Hydrology
Dept. of Oceanogr. and Meteorol., Tex. A & M Univ., College Station, Tex., Final Rep, Proj 154 (Nov 1957).

64. Biswas, K. R., Ghose, B. K., Khemani, L. T. and Ramana Murty, B. V.

Rain Intensity Measurements by Radar Technique
Indian J Meteorol Geophys; Vol 13, Special No, p 147–154 (Mar 1962).

The method adopted for estimating rainfall rates on the basis of echo intensity measurements is explained. By applying the method it is possible to map out readily the areal fine structure of rainfall intensity along a frontal or convergence zone, which would be of interest to meteorologists.

65. Blanchard, D. C.

"Discussion of Raindrop Distributions Made During Project Shower, Hawaii, 1954"
Conference on the Physics of Cloud and Precipitation Particles, Sep 1955, Proceedings, p 213–223, Pergamon Press, New York, 1957.

Concurrent with other "Project Shower" measurements in Hawaii, raindrop size distribution samples were obtained within the clouds with a portable mechanical device. The time rate of change of the drop size distribution was obtained.

66. Blanchard, D. C.

The Distribution of Raindrops in Natural Rain
Gen. Elec. Res. Lab., Schenectady, N. Y., Final Rep, Proj Cirrus, p 81–93 (Jul 1951).

Presents a report on experiments made at Schenectady, N. Y. in 1949 for determining size and distribution of raindrops in natural rainfall, and includes some of their results and conclusions.

67. Blanchard, D. C.

Experiments with Water Drops and the Interaction Between These at Terminal Velocity in Air
Gen. Elec. Res. Lab., Schenectady, N. Y., Final Rep, Proj Cirrus, p 102–130 (Jul 1951).

Suspension of water drops in a vertical wind tunnel permits close observation of the drops, their growth and breakup, subsequent internal circulation and reactions to turbulence and changes in air velocity. Breakup of drops (especially large ones) is due to turbulence or sudden changes in air velocity.

68. Blanchard, D. C.

Raindrop Size Distribution and Associated Phenomena in Hawaiian Rains
Woods Hole Oceanogr. Inst., Woods Hole, Mass., AD-9 370, Rep No 4 (Dec 1952).

69. Blanchard, D. C.

Raindrop Size-Distribution in Hawaiian Rains
J Meteorol; Vol 10, No 6, p 457–473 (Dec 1953).

Filter paper samples of drop-size distribution in orographic rains from non-freezing clouds at cloud base or within the cloud gave narrow distributions, largest drops rarely exceeding 2 mm diameter and drops > 0.5 mm often exceeding $25{,}000/m^3$. These give low values of median drop diameter and radar reflectivity but high liquid-water content.

70. Blanchard, D. C.

A Simple Method for the Production of Homogeneous Water Drops Down to 1 Micron Radius
Woods Hole Oceanogr. Inst., Woods Hole, Mass., AD-31 990, Rep No 8, Contr NONR-798000 (May 1954).

71. Blanchard, D. C.

"The Supercooling, Freezing and Melting of Giant Waterdrops at Terminal Velocity in Air"
Conference on the Physics of Cloud and Precipitation Particles, Sep, 1955, Proceedings, p 233–249, Pergamon Press, New York, 1957.

Giant water drops have been freely suspended in a vertical wind tunnel at temperatures below 0°C. The manner of freezing of these supercooled waterdrops is a function of the wet bulb temperature. At temperatures above $T_W - 4$ or -5°C, a shell of ice, first forming on the bottom of the drop will envelope the drop and then freeze inward.

72. Blanchard, D. C.

The Use of Sooted Screens for Determining Raindrop Size and Distribution
Gen. Elec. Res. Lab., Schenectady, N. Y., Final Rep, Proj Cirrus, p 94–101 (Jul 1951).

According to this report the use of a mesh screen sooted with a thin layer of carbon will eliminate a disadvantage of the Bentley flour technique (the effect of wind) in determining size and distribution of raindrops.

73. Blevis, B.C.

Losses Due to Rain on Radomes and Antenna Reflecting Surfaces
IEEE Trans Antennas Propagation; Vol AP-13, No 1, p 175–176 (Jan 1965).

Presents a theoretical study to assess the extent of losses due to rain falling on a radome enclosing a paraboloidal antenna. The loss produced by water layers collecting on the reflector is less severe.

74. Borchardt, H.

Physical and Technical Principles of the Application of Radar in Meteorology after Experiences with the Weather-Radar of the Institute of Microwaves at the German Experimental Installation of Aeronautics
Deutsche Versuchsanstalt für Luftfahrt, Mühlheim (Ruhr), Ger., Rep No 109 (Mar 1960).

Discusses reflection and attenuation in precipitation areas, antenna properties and atmospheric influences upon the propagation of microwaves.

75. Borovikov, A.M., Kostarev, V.V.

The Accuracy of Measuring Cloud Heights by Radar
Tr Tsentr Aerolog Observ; No 36, p 37–42 (1961); ATS-33Q68R.

76. Borovikov, A.M., Mazin, I.P. and Nevzorov, A.N.

Some Results of the Measurement of the Size Distribution of Large Particles in Clouds
Tr Tsentr Aerolog Observ; No 36, p 3–12 (1961); ATS-31Q68R.

77. Boucher, R.J.

Analysis of Rain Drop Size Measurements and the Empirical Relationship between Radar Reflectivity and Rate of Rainfall
Mt. Washington Observ., New Hampshire, Final Rep, Contr AF 19(122)-399 (1952).

78. Boucher, R.J.

Results of Measurements of Raindrop Size
Ill. State Water Surv., Urbana, Ill., Bull No 41, p 293–297 (1952).

A technique of measuring raindrop size distribution using a nylon screen is described. Results of 63 rain samples obtained by this method at Cambridge give a value of $Z = 269\ R^{1.55}$ by a regression of log Z on log R.

79. Boucher, R.J.

Synoptic-Dynamic Implications of 1.25 cm Vertical Beam Radar Echoes
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 179–188.

More than 1000 hrs of radar records taken with the APS-34 1.25 cm vertical beam radar during a four-year period have been readily classified into four clearly recognizable types. Maximum attainable hourly rates of precipitation are empirically related to the depth of detectable echo.

80. Boucher, R.J. and Bartnoff, S.

A Comparison of Theoretically Derived and Observed Drop-Size Distributions in Clouds and Rain
Tufts Univ., Medford, Mass., AD-71 353, Rep No 4 (Jul 1955).

81. Boucher, R. J. and Wexler, R.

Research in Radar Meteorology
Allied Res. Associates, Inc., Boston, Mass., Final Rep
Pt 3, Contr AF 19(604)-3492 (Mar 1959).

Research on the melting of hail indicates that along the 20°C wet adiabat hail of about 1 cm diameter at the 4 km level will completely melt by the time it reaches the surface.

82. Bowen, E. G.

Recent Work of the Radiophysics Division, C.S.I.R.O.
IRE Proc (Australia); Vol 12, p 99–108 (1951).

Includes an account of the structure of "freezing" and non-freezing rain as shown by radar from the air and ground. A transmitter carried by balloon is used to measure raindrop sizes and water content in the air.

83. Bowen, E. G. and Davidson, K. A.

A Raindrop Spectrograph
Quart J Roy Meteorol Soc; Vol 77, No 333, p 445–449 (Jul 1951).

Describes a raindrop spectrograph in which drops fall through a wind tunnel onto a moving strip of sensitized paper.

84. Boyd, J. E., Martin, R. A., Yoe, C. and Brown, F. B.

Effect of Atmospheric Conditions on the Propagation Characteristics of Electromagnetic Waves in the Microwave Region
Georgia Inst. of Tech., State Eng. Exp. Sta., Atlanta, Ga.,
Progr Rep No 21, Contr W28-009-ac-175 (Feb 1949).

Preliminary results of measurements of propagation at L, S, and X bands over about 50 miles of rough paths in Georgia are presented.

85. Boyenval, E. H.

Echoes from Precipitation using Pulsed Doppler Radar
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960),
Sponsor: Am. Meteorol. Soc., p 57–64.

The observation of meteorological echoes using a 3 cm pulsed Doppler radar is described. Under certain conditions drop size distributions are obtained for all heights from 1000 m to just below the 0°C level.

86. Braham, R. R.

What Is the Role of Ice in Summer Rain – Showers
J Atmos Sci; Vol 21, No 6, p 640–645 (Nov 1964).

Recent observations indicate that ice pellets and snow pellets are present in most convective clouds in the Central United States by the time these clouds reach top temperatures of −10°C. The ice pellets are usually preceded by the development of liquid precipitation particles large enough to produce rain by coalescence with cloud droplets.

87. Bricard, J. and Veret, C.

Research on the Propagation of the Visible and Infrared Light Across Haze and Fog
Compt Rend; Vol 238, No 4, p 503–505 (Jan 1954).

The optical density of an atmosphere containing water droplets was measured for different wave lengths. For haze the optical density was below 2 per km in the visible part (at 0.4 μ) and 10 to 100 times less in the infrared (around 10 μ).

88. Bridges, J. E.

A Survey of Five Radar Remote Measurement Techniques to Measure the Particle Drop Size Distribution of Water Clouds and Rain
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 130.

89. Brook, M.

Relationship between the Initial Radar Echo and the Initial Electric Field in Isolated Thunderstorm Cells
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 61–68.

The results of a field study on the initiation of electric fields in isolated thunderstorms are presented and compared with the findings of previous studies. The initial radar echo is found to precede the initial electric field by an average time of about 10 minutes. The top of an echo when it first evidences electrification is always found above approximately 21,000 ft., i.e., colder than −10°C.

90. Brooks, C. E. P.

Frequency Distribution of Hailstone Sizes
Quart J Roy Meteorol Soc; Vol 70, No 305, p 227–228 (Jul 1944).

91. Browning, K. A.

The Growth of Large Hail in a Steady Updraught
Quart J Roy Meteorol Soc; Vol 89, No 382, p 490–507 (Oct 1963).

92. Browning, K. A., Ludlam, F. H. and Macklin, W. C.

Density and Structure of Hailstones
Quart J Roy Meteorol Soc; Vol 89, No 379, p 75–84 (Jan 1963); see also: Dept. of Meteorol., Imperial Coll. of Sci. and Tech., London, Tech Note No 10, Contr AF 61 (052)-254 (Dec 1961).

Experimental study of ice accretions, together with estimates of the typical conditions in the cumulonimbus of cold air masses, is used to deduce the density of ice in the hailstones produced by these clouds.

93. Browning, K. A. and Ludlam, F. H.

Radar Analysis of a Hailstorm
Imperial Coll. of Sci. and Tech., Dept. of Meteorol., London, Tech Note No 5, Contr AF 61 (052)-254 (1960).

94. Buchanan, T. J.

Balance Methods for the Measurement of Permittivity in the Microwave Region
Inst Elec Eng Proc; Vol 99, No III, p 61 (1952).

95. Buchanan, T. J. and Grant, E. H.

Phase and Amplitude Balance Methods for Permittivity Measurements
Brit J Appl Phys; Vol 6, p 64–66 (Feb 1955).

96. Bullrich, K.

Measurements on Scattered Light in Haze and Fog
Meteorol Rundsch; Vol 13, No 1, p 21–29 (Jan/Feb 1960).

During the winter period 1958-1959, numerous measurements of light scattering in haze and fog were carried out at Mainz University. These measurements aimed at determining the intensity of scattered light as a function of scattering angle, the intensity of both polarization components i_1 and i_2 of the scattered light as a function of the scattering angle and the excitation of the beam. The measurements were made with an artificial unpolarized beam of light in the wave lengths of 420, 555, and 670 mμ.

97. Bullrich, K.

"Mie Scattering of an Atmospheric Air Volume"
Electromagnetic Scattering, p 191–207, Pergamon Press, New York, 1963.

Results of calculations of the spectral scattering functions and polarization functions for a scattering volume of turbid air are presented. The scattering cross-section and the scattering functions $i_1(\alpha, \varphi)$ and $i_2(\alpha, \varphi)$ were calculated for particles with size parameter values $\alpha = 2(0.2)159$ and a refractive index 1.5, using Mie's theory.

98. Bullrich, K.

The Role of Haze and Ice Particles in the Atmosphere in the Scattering of Light
Deutscher Wetterdienst in der U.S. Zone, Bad Kissingen, Ger. Rep No 12, p 92–93 (1950).

Comparison of theoretical values of scatter function with those observed by several investigators shows very different results according to number, size and transparency of particles.

99. Bussey, H. E.

Microwave Attenuation Statistics Estimated from Rainfall and Water Vapor Statistics
IRE Proc; Vol 38, p 781–785 (Jul 1950).

Annual distribution curves are obtained for values of total atmospheric attenuation over a 50 km path and a 1 km path at Washington, D.C. These results are obtained by analyzing the available meteorological data, although these are usually ill-suited to the purpose; theoretical coefficients are used for converting into radio attenuation values.

100. Byers, H. R., Moses, H. and Harney, P. J.

Measurement of Rain Temperature
J Meteorol; Vol 6, No 1, p 51 (1949).

101. Caton, P. G. F.

A Study of Raindrop Size Distributions in the Free Atmosphere
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 136.

102. Chandrasekhar, S.

Radiative Transfer
Clarendon Press, Oxford, 1950.

This is a textbook which covers in great detail the modern theories of radiative transfer, scattering, polarization, emission absorption, diffuse reflection, Rayleigh scattering and scattering by planetary atmospheres, and radiation in atmosphere with varying geometrical, physical and chemical properties.

103. Changnon, S. A. and Bigler, S. G.

On the Observation of Convective Clouds and the Radar-Precipitation Echoes within Them
Bull Am Meteorol Soc; Vol 38, No 5, p 279–282 (May 1957).

Data collected in Illinois on the behavior of growing cumulus clouds and their associated radar echoes are reviewed and the results are compared to findings in other regions.

104. Changnon, S. A. and Huff, F. A.

Studies of Radar-Depicted Precipitation Lines
Ill. State Water Surv., Urbana, Ill., AD-252 197, Sci Rep No 2, Contr AF 19(604)4940 (Feb 1961).

Three separate studies were made: 1. a radar climatological description of precipitation lines as displayed by the CPS-9, 2. a similar investigation using the APS-15, and 3. the radar characteristics of precipitation lines associated with heavy rainstorms.

105. Chmela, A. C.

Hail Occurence in New England: Some Relationships to Radar Echo Patterns
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 489–497.

Five years' data indicate that true hail occurred on 114 days. July has the greatest frequency of hail days and hail 1" and larger. The most frequently observed hail has a diameter of 1/4". Median values are: maximum diameter, 1/2; ratio of maximum to minimum size in a hail fall, 2; number concentration, 0.1 g/m^3; hail fall duration, 4 min; hail starts 2 min after heavy rain begins. A line echo pattern on the radar PPI is associated with 70% of days with hail 1" or larger.

106. Coates, R. J.

The Measurement of Atmospheric Attenuation at 4.3 mm Wavelength
Naval Res. Lab., Washington, D.C., AD-128 210, Rep No 4898 (Apr 1957).

107. Cochran, H. B.

A Numerical Description of New England Squall Lines
M.S. Thesis, Mass. Inst. of Tech., Cambridge, Mass. (Jan 1961).

108. Collie, C. H., Hasted, J. B. and Ritson, D. M.

The Dielectric Properties of Water and Heavy Water
Phys Soc London Proc; Vol 60, No 2, p 145–160 (Feb 1948).

109. Collis, R. T. H.

Radar Precipitation Measurements
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 142.

110. Collis, R. T. H.

A Radar Raingauge
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 83–87.

At microwave frequencies radio energy is attenuated by precipitation intervening in the path of propagation. The degree of attenuation can be related to rainfall rate. A simple technique is described for measuring attenuation by comparing the relative signal intensities of the echoes reflected by two or more fixed targets.

111. Collis, R. T. H., Honey, R. C. and Fernald, F. G.

Study of Techniques for Measuring, Rainfall by Reference to Radar Attenuation
Stanford Res. Inst., Menlo Park, Calif., Final Rep, Contr Cwb-10488 (Jun 1963).

An experimental program to study techniques for measuring rainfall by reference to radar attenuation is reviewed. The program, which was carried out from 1960 to 1963, used an 8.7-mm pulsed radar from which energy was reflected over a fixed path (approximately 8 km long) by a series of passive reflectors.

112. Collis, R. T. H. and Ligda, M. G. H.

A Radar Raingauge
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 391–395.

This is a progress report on the development of a technique for measuring rainfall by reference to radar attenuation.

113. Cooper, B. F.

Balloon Borne Instrument for Telemetering Raindrop-Size Distribution and Rainwater Content of Clouds
Australian J Appl Sci; Vol 2, No 1, p 43–55 (1951).

An instrument is described and illustrated which gives quantitative information on raindrop size and water content per unit volume of cloud. The device is carried by radiosonde type balloon and the data are transmitted to the ground by radio.

114. Crossley, A. F.

The Fall of Hail Alongside Cloud
Meteorol Mag; Vol 91, No 1075, p 33–39 (Feb 1962).

Hail forming cloud is usually associated with strong wind shear in the vertical with the winds at the higher levels being stronger than those lower down. It is possible for hail to be carried forward in the anvil and to fall ahead of the cloud itself. In this article a theoretical method is described for estimating the extent to which hail of various sizes may be displaced laterally from the thundercloud.

115. Cumming, W. A.

The Dielectric Properties of Ice and Snow at 3.2 cm
J Appl Phys; Vol 23, No 7, p 768–773 (1952).

116. Cunningham, R. M. and Atlas, D.

Growth of Hydrometeors as Calculated from Aircraft and Radar Observations
Toronto Meteorological Conference, Toronto, Can. (1953), Sponsor: Roy. Meteorol. Soc., Lon., p 276–289.

117. Curcio, J. A., Drummeter, L. F., Petty, C. C., Stewart, H. S. and Butler, C. P.

An Experimental Study of Atmospheric Transmission
J Opt Soc Am; Vol 43, No 2, p 97–102 (Feb 1953).

An experimental investigation was made to determine the general characteristics of the spectral transmission of the atmosphere in the vicinity of Washington, D.C., on the Chesapeake Bay, in the Gulf of Mexico, and in the Central Pacific. Transmission measurements were made at the wavelengths of approximately 15 of the Hg discharge lines in the interval 2500 A to 6000 A. Values of the spectral atmospheric attenuation coefficients (km^{-1}) have been computed.

118. Das, Phanindramohan

Influence of Wind Shear on the Growth of Hail
J Atmos Sci; Vol 19, No 5, p 407–414 (Sep 1962).

The physical implication of this suggestion is examined by making computations on the growth of hailstones in a model cloud under vertical wind shear. The computations are based essentially on the Schumann-Ludlam formulation of the hail problem.

119. Dean, L. A., Jones, D. M. A. and Atlas, D.

Drop-Size History During a Shower
J Meteorol; Vol 11, No 3, p 256–257 (Jun 1954).

Two different drop-size spectra are shown, indicating that c and k in expression $Z = cR^k$ differ from storm to storm. It is also suggested that variation of k is small and is given by $6/(3+b)$ where b is given by relation between velocity and drop diameter, $v = ad^b$.

120. Decker, F. W. and Kershaw, H.

Instrumentation and Techniques for Army Weather Observation
Oreg. State Coll., Dept. of Phys., Corvallis, Oreg., 7th Quart Tech Rep Proj DA 3-99-00-100 (Sep-Nov 1958).

Expansion of several studies would be beneficial to meteorology applicable to military use with special attention to the bright band changes during the passage of showers indicative to topographic effects. This is demonstrated in a series of graphs comparing the simple extrapolation of the movement of the existing radar echo within a 10- to 20-mile area.

121. Deirmendjian, D.

Complete Microwave Scattering and Extinction Properties of Polydispersed Cloud and Rain Elements
Rand Corp., Santa Monica, Calif., Rep No RAND-R-422-Pr, AD-426 139 (Dec 1963).

122. Dennis, A. S.

Measurements of Forward Scatter from Rain at 9.05 gc
Stanford Res. Inst., Menlo Park, Calif., Res Memo 3 and 4, Contr NASR-49-(02), SRI Proj 3773 (1962).

123. Dennis, A. S.

"Precipitation Scatter as an Interference Source in Communication Satellite Systems"
1962 IRE International Convention Record (U.S.A.), Vol 10, Pt 1, p 145–151, 1962.

The theory of scattering of radio waves at s.h.f. by rain, snow and hail is reviewed. Back-scattering cross-section of particles, and radar reflectivity of typical storms are treated. The geometry of precipitation interference at ground terminal due to distant high-power transmitters is considered both for c.w. and for pulse transmissions. The interference power level is compared with typical noise levels and shown to be important.

124. Diem, M.

The Size of Raindroplets
Tech. Hochsch. Meteorol. Inst., Karlsruhe, Ger., Final Tech Rep Contr DA-91-591-EUC-1477 (Oct 1961).

At a constant liquid water content the intensity of precipitation changes approximately by an almost constant factor together with the number of droplets. With the widening of the spectra, and the increase in the intensity of rain, no simultaneous increase in the number of big drops occurs.

125. Dingle, A. N.

Agglomeration of Cloud Particles and Project Hi-Cue Participation
Univ. of Mich., Office of Res. Admin., Ann Arbor, Mich., Final Rep
Contr AF 19(604)-6143 (Jun 1962).

Data collected at Flagstaff under Project Hi-Cue, 1961, are analyzed. The data logs for the raindrop-size spectrometer, the two-theodolite pibals, and the APQ-40 radar are included. The results of basic computations on the raindrop-size and the pibals are reported.

126. Dingle, A. N.

Raindrop-Size Studies
Univ. of Mich., Coll. of Eng., Ann Arbor, Mich., AD-437 861, Rep No 05016 2F, Contr AF19 628 281 (Oct 1963).

Qualitative analysis of raindrop-size distributions in heavy showers indicates that some of their prominent features can be explained by the combined effects of wind-shear sorting of drops and of the splashing of large drops upon surface obstructions. Computational studies which account for the effects of cloud-droplet accretion, raindrop coalescence, and evaporation processes indicate that, in steady-state rain, the origin of large drops lies in snow-aggregation processes above the melting layer.

127. Dingle, A. N. and Hardy, K. R.

Description of Rain by Means of Sequential Raindrop Size Distributions
Quart J Roy Meteorol Soc; Vol 88, No 377, p 301–314 (Jul 1962).

The photoelectric raindrop size spectrometer has made possible the resolution of drop-size spectra in natural rains to 1 min intervals of time. Characteristics of the drop-size spectra thus obtained and their time sequences are discussed.

128. Doherty, H. L.

Z-R Relationships Deduced from Forward Scatter Doppler Measurements
J Atmos Sci; Vol 21, No 6, p 683–697 (Nov 1964).

Measurements were made at 9400 Mc/s of the radio wave scattering from raindrops. The experiment involved forward scattering over a short link and included Doppler frequency measurements which provided data on the vertical velocity of the raindrops. The drop-size distribution $N(D)\,dD = 0.103 \exp(-45^{-0.214D})\,dD$ is deduced without measurement of drop sizes. The Z-R relationship best fitting all the data is shown to be $Z = 244R^{1.39}$ in the usual units.

129. Doherty, L. H. and Stone, S. A.

Forward Scatter from Rain
IRE Trans Antennas Propagation; Vol AP-8, No 4, p 414–417 (Jul 1960).

130. Donaldson, R. J.

Analysis of Severe Convective Storms Observed by Radar
J Meteorol; Vol 15, No 1, p 44–50 (Feb 1958).

131. Donaldson, R. J.

Drop-Size Distribution, Liquid Water Content, Optical Transmission and Radar Reflectivity in Fog and Drizzle
5th Weather Radar Conference, Asbury Park, N. J. (Sep 1955), Sponsor: U.S. Army Signal Corps, p 275–280.

A detailed investigation is reported which confirms earlier findings that radar measurements of liquid water content in fog yield consistently low values. True liquid water contents are 50% greater than the measured values.

132. Donaldson, R. J.

"Hail"
Handbook of Geophysical and Space Environments, Chap 5, Sec. 5.1.2, McGraw-Hill, New York, 1964.

133. Donaldson, R. J.

The Measurement of Cloud Liquid-Water Content by Radar
J Metoerol; Vol 12, No 3, p 238–244 (Jun 1955).

134. Donaldson, R. J.

Proceedings of the Colloquium on Microwave Meteorology, Aerosols and Cloud Physics
Colloquium on Microwave Meteorology, Aerosols and Cloud Physics, McGill Univ., Montreal, Can. (Sep 1950), Sponsor: A.F. Cambridge Res. Center.

135. Donaldson, R. J.

Radar Observations of a Tornado Thunderstorm in Vertical Section
U.S. Weather Bur., Washington, D.C., Rep No 8, Nat. Severe Storms Proj (1962).

136. Donaldson, R. J.

Radar Reflectivity Profiles in Thunderstorms
J Meteorol; Vol 18, No 3, p 292–305 (Jun 1961).

137. Donaldson, R. J.

Range Distortion of Thunderstorm Reflectivity Structure
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 165–174.

138. Donaldson, R. J.

The Shape of the Hail Area in Thunderstorms
J Meteorol; Vol 18, No 3, p 416–419 (Jun 1961).

139. Donaldson, R. J.

Vertical Profiles of Radar Echo Reflectivity in Thunder Storms
7th Weather Radar Conference, Miami Beach, Fla. (Nov 1958), Sponsor: Am. Meteorol. Soc., p B8–B16.

140. Donaldson, R. J. and Atlas, D.

"Attenuation and Back-Scattering"
Handbook of Geophysical and Space Environments, Chap 9, Sec 9, McGraw-Hill, New York, 1964.

141. Donaldson, R. J., Atlas, D., Paulsen, W. H., Cunningham, R. M. and Chmela, A. C.

Quantitative 1.25 cm Observations of Rain and Fog
Conference on Radio Meteorology, Univ. of Tex., Austin, Tex. (Nov 1953), Sponsor: Bur. of Eng. Res., Univ. of Tex., p VII–6.

142. Donaldson, R. J. and Atlas, D.

Radar in Tropical Meteorology
AFCRL Surv Geophys; No 158 (Sep 1964).

143. Donaldson, R. J. and Sissenwine, N.

"Hail"
Handbook of Geophysics for Air Force Designers, Chap 6, Sec 2, Macmillan, New York, 1957.

144. Donaldson, R. J. and Tear, R. T.

Distortions in Reflectivity Patterns by Antenna Side Lobes
10th Weather Radar Conference, Washington, D.C. (Apr 1963), Sponsor: Am. Metoerol. Soc., p 108 – 115.

145. Douglas, R. H.

Hail Size Distributions
11th Weather Radar Conference, Boulder, Colo. (Sep 1965), Sponsor: Am. Meteorol. Soc., p 146.

146. Douglas, R. H., Barklie, R. H. D. and Gokhale, N. R.

Alberta Hail, 1958 and Related Studies. Part I. Alberta Field Studies. Part II. Growth by Accretion in the Ice Phase. Part III. The Freezing of Supercooled Water Drops.
MacDonald Phys. Lab., McGill Univ., Montreal, Can., AD-225 399, Sci Rep No MW-30, Contr AF 19(604)-2065 (Jul 1959).

147. Douglas, R. H. and Hitschfeld, W.

Studies of Alberta Hailstorms, 1957
MacDonald Phys. Lab., McGill Univ., Montreal, Can., AD-152 578, Sci Rep No MW-27, Contr AF 19(604)-2065 (May 1958).

The storms on 5 hail days were examined and the patterns of their radar echoes were related to hail reports.

148. Dyck, H. D. and Mattice

A Study of Excessive Rainfall
Monthly Weather Rev; Vol 69, p 293 – 301 (Oct 1941).

149. Eldridge, R. G.

Measurement of Drop Size Distribution and Liquid Water Content in Natural Clouds – Some Cloud Observations with the Infrared Spectrograph
Mass. Inst. of Tech., Dept. of Meteorol., Cambridge, Mass., AD-4 408, Rep No 3 (Dec 1952).

150. Elliott, H. W.

Attenuation of Radar Waves in Snowstorms
Radio and Elec. Eng. Div., Nat. Res. Counc. of Can., AD-214 064, Rep No ERB-211 (Sep 1948).

151. Farnsworth, G. W., Jones, D. M. A., Neill, J. C. and Stout, G. E.

Research Study on Intensity of Surface Precipitation Using Radar Instrumentation
Ill. State Water Surv., Meteorol. Lab., Urbana, Ill., 1st, 2nd, 4th and 5th Quart Progr Reps, Contr DA 36-039-SC-42446 (Jun 1952 – Jul 1953).

A photographic technique for measuring particle-size distribution in precipitation is described and a diagram of the raindrop camera and the results of measurements are given.

152. Flanders, A. F.

Results of Precipitation Measurements with Weather Bureau Radars
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 150.

153. Fleischer, R., Oshima, M., Roark, P., Straka, R. M. and DeJong, M.

Effects of the Atmosphere on Radio Astronomical Signals
Rensselaer Polytech. Inst., Troy, N. Y., Final Rep, Contr AF 19(604)-8055 (Apr 1962).

Discusses thermal radiation at microwave frequencies.

154. Forsgren, S.K.H. and Perers, O.F.

Vertical Recording of Rain by Radar
Chalmers Tekniska Högskola, Göteborg, Swed., Rep No 107 (1951).

Gives the results of tests made in the summer of 1949 at Göteborg with an AN/CPN-6 radar on 3.2 cm wave length, and 7.5 kw output and with recordings on 2 synchroscopes, one used for visual recordings.

155. Foster, D.S.

Aviation Hail Problem
World Meteorol. Organ., WMO No 109, TP 47 (1961).

Some climatology statistics of aviation hail encounters over the United States is shown. The hail-thunderstorm ratio and its geographical and seasonal significance is discussed. Part II includes a very brief summary of the work that has been done in detecting hailstorms by radar – both ground based and airborne.

156. Franz, K.

Attenuation of Very Short Electric Waves during Passage through Clouds and Fog
Hochfrequenz-Tech Elektroakust; Vol 55, No 5, p 141–143 (May 1940).

This theoretical discussion shows that attenuation is controlled by drops of liquid water and not by water vapor. The degree of attenuation depends on amount of liquid water rather than drop size distribution.

157. Frisby, E.M.

A South Dakota Hail Study, 1954–1959
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 143–150.

A climatological study has been made for the last six summer seasons of the frequency and incidence of hail occurrence across the state of South Dakota.

158. Fujiwara, M.

An Analytical Investigation of the Variability of Size Distribution of Raindrops in Convective Storms
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 159–166.

The variability of Z-R points for 1-min data and regression lines for storms were reviewed in comparison with three major rainfall types.

159. Fujiwara, M.

Raindrop Size Distributions with Rainfall Types and Weather Conditions
Ill. State Water Surv., Meteorol. Lab., Univ. of Ill., Urbana, Ill., AD-297 944, Res Rep No 8, Contr DA-36-039-SC-87280 (1961).

This paper investigated the relationship between the variability of the raindrop size distributions and weather conditions on the basis of raindrop, radar, and synoptic weather data. The first section reviews the variability of the observed Z-R values in relation to rainfall types; the second interprets the behavior of Z-R points in terms of $N_D - D$ relationships proposed by the author.

160. Fujiwara, M.

Z-R Equation in Various Storms
11th Weather Radar Conference, Boulder Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 154.

161. Funakawa, K. and Kato, J.

Experimental Studies of Propagational Characters of 8.6 mm Wave on the 24 km Path
J Radio Res Lab (Japan); Vol 9, p 351 – 367 (Sep 1962).

The experiments described were carried out nearly all the year round, using a pulse magnetron transmitter with a peak power of 30 kw. Rain gauges were used at several points along the transmission path and measurements were made to determine the relation between signal attenuation and rainfall rate.

162. Georgii, W.

Measure Flights for the Research of Aerophysical Problems: Measurement of Cloud Elements, Atmospheric Vertical Velocity, Atmospheric Ozone Content
Deutsche Forschungsanstalt für Segelflug, E. V. Institut für Flugforschung, Final Rep, Contr DA 91-508-EUG-297 (1 Mar 1958 – 30 Sep 1959).

Describes methods for direct and indirect determination of drip sizes in clouds.

163. Geotis, S.

Some Radar Measurements of Hailstorms
J Appl Meteorol; Vol 2, No 2, p 270 – 275 (Apr 1963);
see also: 9th Weather Radar Conference, Kansas City, Mo., Oct 1961, Sponsor: Am. Meteorol. Soc., p 133 – 138

The radar reflectivity of thunderstorms at 10 cm is shown to be a good indicator of hail and a rough measure of its size. The physical characteristics of the hailstorms, as deduced from 3- and 10-cm echoes of a large number of New England hailstorms of 1961, are described.

164. Gerhardt, J. R., Tolbert, C. W., Brunstein, S. A. and Bahn, W. W.

Experimental Determinations of the Back-Scattering Cross-Sections of Water Drops and of Wet and Dry Ice Spheres at 3.2 cm
J Meteorol; Vol 18, No 3, p 340 – 347 (Jun 1961).

165. Gerhardt, J. R. and Tolbert, C. W.

Rain Attenuation and Backscattering Measurements at 4.3 Millimeter Wavelength
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 243 – 252.

This is a discussion of one-way rain attenuation measurements made in late 1955 and the first half of 1956, using a 4.3 mm equipment over a 1000 ft path, and by measuring both rainfall amount and drop size distribution using 7 gauges distributed uniformly along the path and dye coated filter paper. A graph shows relation between measured and radar rates of precipitation and drop size distribution; an artificial raindrop device giving uniform distribution along each is treated.

166. Glover, K. M. and Atlas, D.

On the Back-Scatter Cross-Sections of Ice Spheres
Z Angew Math Phys; Vol 14, No 5, p 563 – 573 (Sep 1963).

Ice spheres of diameter D greater than 1.5 wavelengths back-scatter more than ten times as well as equal sized metal spheres. A modified geometrical optics treatment gives results surprisingly agreeing with the exact Mie solution for $4 < \pi D/\lambda < 21$, but predicting cross-sections smaller by a factor of 3 or 4 than the exact theory for larger D/λ.

167. Godard, S.

Description of the 0.86 cm Radar Set Up at Lannemezan
Bull Obs Puy de Dome; Ser 2, No 4, p 175 – 184 (Oct/Dec 1961).

Observations on snow showers, rainfall and clouds are described.

168. Golikov, V. I.

Device for Measuring the Size Spectrum of Spherical Particles and Fog Droplets
TR GL Geofiz Observ; No 109, p 76 – 89 (1961).

Describes a laboratory device for measuring the size spectrum of spherical particles of powder (planes models of sol) and water droplets (droplets in a thin oil film).

169. Grant, E. H.

A Simple and Rapid Method of Measuring the Complex Permittivity of a Liquid
Brit J Appl Phys; Vol 6, p 181 (May 1955).

170. Grant, E. H., Buchanan, R. J. and Cook, H. F.

Dielectric Behavior of Water at Microwave Frequencies
J Chem Phys; Vol 26, No 1, p 156 – 161 (Jan 1957).

171. Griffith, R. M.

A Possible Relation between Condensation Nucleus Concentration and the Drop-Size Distribution of Continuous Warm-Front Rainfall.
J Atmos Sci; Vol 20, No 3, p 198 – 200 (May 1963).

An attempt is made to correlate differences in raindrop size-spectra of continuous warm-front rainfall measured at various locations with the differences in condensation nucleus concentrations at the measuring sites.

172. Griffith, R.

Sizes and Concentrations of Cloud and Precipitation Particles
Army Signal Res. and Develop. Lab., Fort Monmouth, N. J., AD-230 756, Rep No 2086 (Dec 1959).

The results of various measurements of cloud and precipitation particle spectra are summarized. Particle size distributions and concentrations are given as functions of cloud or rainfall type.

173. Grunow, J.

Investigations on the Structure of Precipitation
Hohenpeissenberg Meteorol. Observ., Deutscher Wetterdienst, Germany, (Fed. Repub.), Final Rep, Contr DA-91-591-EUC-1386 (Apr 1961).

Recording devices were employed in order to carry out a continuous measurement of the components of precipitation structure: duration, intensity and drop structure. The frequency distribution of the drop volumes was ascertained minute by minute, and from combined periods the drop spectra were determined.

174. Gunn, R.

Electronic Apparatus for the Determination of the Physical Properties of Freely Falling Raindrops
Rev Sci Instr; Vol 20, No 4, p 291 – 296 (Apr 1949).

Outlines principles, design and calibration of an electric recorder of mass, fall velocity, evaporation rate, and the transported electrical charge of the individual falling raindrops.

175. Gunn, K. L. S. and East, T. W. R.

The Microwave Properties of Precipitation Particles
Quart J Roy Meteorol Soc; Vol 80, No 346, p 522 – 545 (Oct 1954).

Advances in radar meteorology since the fundamental paper by J. W. Ryde, 1951, are reviewed. The principles of radar analysis of precipitation are summarized. Pt. 2 tabulates the refractive index absorption coefficient, back scatter and attenuation of water and ice at different temperatures and wavelengths. Pt. 3 sets out the theory of scattering and absorption by spheres of water, ice and water-coated ice. In Pt. 4 scattering by rain is taken up. Determinations of constants in $Z = aR^b$ are quoted and scattering and attentuation of different wave-lengths shown. Scattering and attenuation by snow and clouds are briefly considered.

176. Gunn, K. L. S. and Kinzer, G. D.

The Terminal Velocity of Fall for Water Droplets in Stagnant Air
J Meteorol; Vol 6, No 4, p 243 – 248 (Aug 1949).

177. Gunn, K. L. S. and Marshall, J. S.

Effect of Wind Shear on Falling Precipitation
J Meteorol; Vol 12, No 4, p 339 – 349 (Aug 1955);
see also: Macdonald Phys. Lab., McGill Univ., Montreal, Can., Sci Rep MW-18, Contr AF 19(122)-217 (Dec 1954).

The effect of shear on the average relationship between the radar scattering parameter of precipitation (z) and the precipitation rate (R) of showers and the effect on size distribution at the ground is considered.

178. Gupta, B. K., Mani, A. and Venkiteshwaran, S. P.

Some Observations of Melting Band in Radar Precipitation Echoes at Poona
Indian J Meteorol Geophys; Vol 12, No 2, p 317 – 322 (Apr 1961).

Describes some observations of melting band in the radar precipitation echoes made at Poona during 1953 – 1955 and an attempt is made to examine the special features associated with the occurrence of these bands. Discussions concern bright bands in thunderstorms and the variation of their heights with time, and the thickness of the melting band and its freezing level.

179. Haddock, F. T.

Scattering and Attenuation of Microwave Radiation through Rain
Naval Res. Lab., Washington, D.C., Unpublished Manuscript, 1948.

180. Hamilton, P. M.

Weather-Radar Attenuation Estimates from Raingauge Statistics
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 321 – 324; see also: Macdonald Phys. Lab., McGill Univ., Montreal, Can., AD-250 196, Sci Rep No MW-32, Contr AF 19(604)-2065 (Jan 1961).

Rainfall rates observed in time at a point in the path of a storm approximate those along a section through the storm at one time; on this basis, estimates of attenuation frequencies at wave lengths 3 cm and 5.7 cm for a summer's storms at Montreal were made. Attenuation at 5.7 cm is less troublesome than at 3 cm, but truly quantitative operation demands 10 cm.

181. Hannaford, D. A.

Meteorological Factors in Space Communication Systems
International Conference on Satellite Communications, Savoy Place, London (Nov 1962), Sponsor: Inst. Elec. Eng., p 280 – 288.

182. Hardy, K. R.

The Development of Raindrop-Size Distributions and Implications Related to the Physics of Precipitation
J Atmos Sci; Vol 20, No 4, p 299 – 312 (Jul 1963); see also: 10th Weather Radar Conference, Washington, D.C. (Apr 1963), Sponsor: Am. Meteorol. Soc., p 163 – 170

Computations of the changes of the raindrop-size distributions with distance fallen are made. One study of this type for the light rain of 31 July 1961 at Flagstaff, Arizona, shows that the observed distribution at the surface must develop from a distribution aloft which has more large drops and fewer small drops than indicated by the Marshall and Palmer distribution.

183. Hardy, K. R. and Dingle, A. N.

Raindrop-Size Distributions in a Cold Frontal Shower
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 179 – 186.

The detailed time resolution of raindrop number, which is obtained by use of the photoelectric raindrop size spectrometer, reveals that the spacial distribution of raindrops in a summer cold frontal shower is not random.

184. Harper, W. G. and Beimers, J. G. D.

The Movement of Precipitation Belts as Observed by Radar
Gr. Brit. Air Ministry, Meteorol. Res. Comm., England, Rep No MRP 1022 (Dec 1956).

Radar records of movement of 103 belts of precipitation at East Hill, Dunstable, in 1947 – 52, mostly associated with cold fronts or occlusions, were compared with radar winds at 50 mb intervals from 950 – 500 mb. Strong support is found for the forecasting rule: Cold fronts and cold occlusions move with a speed equal to the component of the wind across the front at the 700 mb level.

185. Harper, W. G., Ludlam, F. H. and Saunders, P. M.

Radar Echoes from Cumulus Clouds
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 267 – 272.

During carefully coordinated investigations of developing shower clouds by visual and radar methods, radar echoes were observed from cumulus not containing precipitation.

186. Harvard Univ.

Study of Synoptic-Dynamic Influences on the Nature of Cloud and Precipitation Echoes
Blue Hill Meteorol. Observ., Harvard Univ., Milton, Mass., AD-152 502, Rep No AFCRC TR-58-244, Contr AF 19 (604)-950 (Mar 1958).

An investigation was conducted on meteorological radar echoes as observed at Blue Hill, Mass.

187. Hathaway, S. D. and Evans, H. W.

Radio Attenuation at 11 kMc and Some Implications Affecting Relay System Engineering
Bell Syst Tech J; Vol 38, No 1, p 73 – 97 (Jan 1959).

In order to derive rules for engineering radio relay systems at 11 kMc/s, a one-year experiment was conducted in a region of frequent heavy rainfall. Attenuation of paths 27 and 12 miles long was measured, together with rainfall at two-mile intervals along the paths. Implications related to systems engineering are pointed out.

188. Hawkins, H. E. and LaPlant, O.

Radar Performance and Degradation in Fog and Rain
IRE Trans Aerospace Navigational Electron; Vol ANE-6, No 1, p 26–30 (Mar 1959).

189. Henry, W. K. and Griffiths, J. F.

Research on Tropical Rainfall Patterns and Associated Meso-Scale System
Dept. of Oceanogr. and Meteorol., Tex. A & M Univ., College Station, Tex., Proj 311 (Oct 1963).

190. Herman, B. M.

The Effects of Multiple Scattering on Radar Back-Scattering
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 182.

191. Herman, B. M.

Multiple Scatter Effects on the Radar Return from Large Hail
J Geophys Res; Vol 70, No 5, p 1215–1225 (Mar 1965).

Results for optical depth $\tau = 0.48$ show that multiple scattering effects enhance the backscattered signal by about 30%. This correction increases with optical depth, and for the larger hailstorms is probably quite significant.

192. Herman, B. M. and Battan, L. J.

Calculations of Mie Back-Scattering from Melting Ice Spheres
J Meteorol; Vol 18, No 4, p 468–478 (Aug 1961).

Calculations of the normalized back-scattering cross-section σ_b, of ice spheres surrounded by shells of liquid water have been made from an extension of the Mie theory to a two-layer model. Comparisons are made between the theoretical results presented here and experimental measurements of σ_b for melting ice spheres performed by Atlas et al. (1960).

193. Herman, B. M. and Battan, L. J.

Calculations of Mie Back-Scattering of Microwaves from Ice Spheres
Quart J Roy Meteorol Soc; Vol 87, p 223–230 (Apr 1961).

The back-scattering from large ice spheres is shown to be considerably higher than that from water spheres of the same size.

194. Herman, B. M. and Battan, L. J.

"Calculations of the Total Attenuation and Angular Scatter of Ice Spheres"
Electromagnetic Scattering, p 251–259, Pergamon Press, Oxford, 1963.

Calculation of the normalized total attenuation cross-sections, σ_t, for ice spheres up to an α ($\alpha = 2\,a/\lambda$ where a = radius of the sphere and λ = wavelength of the incident radiation) of 10 are presented. In addition, curves of the scattering intensity functions are presented for selected values of α.

195. Herman, B. M., Browning, S. R. and Battan, L. J.

Tables of the Radar Cross Sections of Water Spheres
Inst. of Atmos. Phys., Univ. of Ariz., Tucson, Ariz., Rep No 29 (Dec 1961).

Presents the results of calculations of the scattering cross sections of water spheres for various wavelengths from 0.62 cm to 10 cm at a temperature of 0 °C. At all wavelengths calculations were made also at intervals of 0.02 for values of α from 0.02 to 0.60 for wavelengths of 3.21, 4.67, 5.5, and 10.0 cm. The tables also give the normalized attenuation (σT) scattering (σS), absorption (σA) and back scattering (σS) cross sections.

196. Hertel, P., Straiton, A.W. and Tolbert, C.W.

Dielectric Constant Measurements at 8.6 mm Wavelengths
J Appl Phys; Vol 24, No 7, p 956–957 (Jul 1953).

197. Hiser, H.W.

Comparisons Between a 10-cm and a 5-cm Wavelength Radar for Meteorological Purposes.
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 253–259.

Comparison PPI and RHI photographs have been taken on a 10-cm and on a 5-cm wavelength radar during a one-year period at the University of Miami.

198. Hiser, H.W.

Effects of Radar Propagation on the Problem of Range Attenuation Correction
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 195–202.

There are several items to consider in the range attenuation correction problem. Two of these are: how high are the storm tops, and what is the path of the beam between the radar and the storm? The effects of low-latitude atmospheric propagation conditions upon the path of a horizontally-directed radar beam are illustrated.

199. Hiser, H.W., Conover, L.F. and Senn, H.W.

Investigation of Rainfall Measurement by Radar
Marine Lab., Univ. of Miami, Coral Gables, Fla., AD-135 150, Rep No 57-12, Contr Cwb-9012 (Jun 1957).

Techniques were developed for the estimation of rainfall with radar by integrated radarscope photographs.

200. Hiser, H.W. and Freseman, W.L.

Radar Meteorology
2nd ed., Univ. of Miami, Coral Gables, Fla., 1959.

A fairly elaborate compilation of current information on radar meteorology, constituting a revision of the 1955 edition of a working text on meteorological applications of radar.

201. Hiser, H.W. and Ray, P.R.

Weather Radar Receiving System
Marine Lab., Univ. of Miami, Coral Gables, Fla., AD-251 052L, Rep No 8942-4, Contr NOa(s) 59-6217-c (Jul 1960).

202. Hitschfeld, W. and Berdan, J.

Errors Inherent in the Radar Measurement of Rainfall at Attenuating Wavelength
J Meteorol; Vol 11, No 1, p 58–67 (Feb 1954).

The equation

$$R = \frac{r^{B/A}\, e^{y/A}}{\left[\left(\frac{1}{a}\right)^{\alpha} - \frac{\alpha C}{A}\int_0^r r^{B\alpha/A}\, e^{y^{\alpha}/A}\, dr\right]^{1/\alpha}}$$

for the rate of rainfall R at range r from the radar is derived.

203. Hitschfield, W., Gunn, K. L. S. and Marshall, J. S.

Size Distributions Generated by a Random Process, A. – The Distribution with Size of Aggregate Snowflakes, B.
McGill Univ., Montreal, Can., AD-98 724, Rep No MW-20 (Sep 1956).

204. Hodson, M. C. and Peter, T. V.

Observations of the Ellipticity of Raindrops Using a Polarized Radar System
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 188.

205. Hogg, D. C. and Semplak, R. A.

The Effect of Rain on the Noise Level of a Microwave Receiving System
IEEE Proc; Vol 48, No 12, p 2024–2025 (Dec 1960).

See Abstract No. 206.

206. Hogg, D. C. and Semplak, R. A.

The Effect of Rain and Water Vapor on Sky Noise at Centimeter Wavelengths
Bell Syst Tech J; Vol 40, No 5, p 1331–1349 (Sep 1961).

Measurements of sky noise temperature at a frequency of 6.0 kmc have been made for various conditions of absolute humidity and precipitation.

207. Hogg, D. C. and Semplak, R. A.

Estimated Sky Temperature Due to Rain
IEEE Proc; Vol 51, No 3, p 499–500 (Mar 1963).

Estimates sky temperature for various rainfall rates for $1 \leqslant \lambda \leqslant 10$ cm based on 5 cm radiometer observations.

208. Hogg, D. C., Semplak, R. A. and Gray, D. A.

Measurements of Microwave Interference at 4 Gc Due to Scatter by Rain
IEEE Proc; Vol 51, No 3, p 500 (Mar 1963).

209. Holzer, W.

Atmospheric Attenuation in Satellite Communications
Microwave J; Vol 8, No 3, p 119–125 (Mar 1965).

Presents a method for computing conservative margins to compensate for atmospheric attenuation.

210. Hood, A. D.

Quantitative Measurements at Three and Ten Centimeters of Radar Echo Intensities from Precipitation
Nat. Res. Counc. of Can., Ottawa, Can., NRC No 2155 (Jun 1950).

The analysis proved that the rate of fall in rainstorms can be measured by radar with reasonable accuracy. Simultaneous quantitative measurements at 3 and 10 cm agree with both theory and previous experimental results showing that radar echoes are dependent on drop size distribution, and are proportional to the sum of the sixth power of the drop diameters contained in a unit volume. Quantitative measurements have given an absolute comparison of X-band and S-band performance and have illustrated the limitations of X-band as a useful frequency in meteorological work.

211. Hooper, J. E. N. and Kippax, A. A.

The Bright Band – A Phenomenon Associated with Radar Echoes from Falling Rain
Quart J Roy Meteorol Soc; Vol 76, p 125–132 (Apr 1950).

Frontal rain when illuminated by radar transmission gives rise to echoes which exhibit a characteristic layer of greater intensity near to the freezing level. Observations which establish the height of this layer or "bright band," relative to that of the freezing level, are described.

212. Hooper, J. E. N. and Kippax, A.A.

Radar Echoes from Meteorological Precipitation
Proc Inst Elec Engrs; Pt 1, Vol 97, No 105, p 89–95 (May 1950).

This is an illustrated article reviewing recent investigations of the theory, apparatus and application of radar techniques to detection of rain, snow and storms for research into the physics of storms, precipitation, etc. and for short range forecasting.

213. Horton, R. E.

Statistical Distribution of Drop Sizes and the Occurrence of Dominant Drop Sizes in Rain
Am Geophys Union Trans; Vol 29, No 5, p 624–630 (Oct 1948).

214. Houghton, H. G. and Radford, W. H.

On the Measurement of Drop Size and Liquid Water Content in Fogs and Clouds
Papers Phys Oceanogr Meteorol (MIT); Vol 6, No 4 (1938).

215. Hudson, H. E., Stout, G. E. and Huff, F. A.

Rainfall Studies using Rain-Gage Networks and Radar
Am Soc Civil Eng Proc; Vol 79, No 178 (Mar 1953).

The results of three years' work on concentrated rain-gage networks and measurements of rainfall extent and intensity by means of radar are described. It is concluded that radar is able to depict rainfall extent better than rain gaging, and that radar can measure rainfall intensities as ably as do the rain-gage networks generally used.

216. Huebner, G. L., Moyer, V. E. and Sanford, T. E.

Radar and Sferics Investigation of Texas Thunderstorms
Dept. of Oceanogr. and Meteorol., Tex. A & M Univ., College Station, Tex., Final Rep. (May 1962).

217. Huff, R. A., Neill, J. C. and Spock, M.

Evaluation of a Low-Powered 3-CM Radar for Quantitative Rainfall Measurements
Ill. State Water Surv., Urbana, Ill., AD-96 495, Rep No 4, Contr DA 36-039-SC-64723 (1956).

218. Hull, B. B.

Hail Size and Distribution
Quartermaster Res. and Eng. Command, Natick, Mass., AD-157 400, Tech Rep No EP-83 (Feb 1957).

Basic information is provided on frequency of occurrence and geographical distribution of hail throughout the world.

219. Hunsucker, R. D. and Decker, F. W.

Observations of the Relationship between Raindrop-Size Distribution and the Existence of Radar Bright-Layers
7th Weather Radar Conference, Miami Beach, Fla. (Nov 1958), Sponsor: Am. Meteorol. Soc., p B33–B34.

> Preliminary analysis of statistical data on raindrop-size distribution at Oregon State College, utilizing the rain drop camera, has revealed a relationship between the raindrop size distribution type and the existence of radar bright layers.

220. Hunter, I.

Attenuation of Microwaves in the Troposphere
Marconi Rev; Vol 27, No 154, p 122–142 (3rd Quart. 1964).

> Discusses attenuation by precipitation.

221. Imai, I.

Attenuation of Microwaves through Rain for Various Drop Size Distributions
J Meteorol Soc Japan; p 65–71 (Nov 1957).

> The attenuation of microwaves by rain at 3.2, 5.7, and 10 cm wave lengths are computed. By using Laws and Parsons' drop size distributions, respective formulas for the three wave lengths, $0.007R^{1.3}$, $0.0013R^{1.1}$ and $0.0003R$, are obtained. Calculations based on drop size data obtained by the M.R.I. group show that the attenuation at 3.2 cm, for a given rainfall rate R, is largely dependent on radar reflectivity Z for $R > 1$ mm/hr.

222. Imai, I.

A Fitting Equation for Raindrop-Size Distributions in Various Weather Situations
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 149-A.

223. Imai, I.

Precipitation Streaks and Raindrop Size-Distribution
Papers Meteorol Geophys (Japan); Vol 7, No 2, p 107–123 (Jul 1956).

> An analysis is made of a continuous record of raindrop size distributions obtained at the ground, and an explanation is given in terms of the theory of precipitation streak. Considering the effects of evaporation and collision during fall, and also an effect resulting from the drop counting technique in which drops are classified by size, the size distributions of raindrops in the generating cell are presumed to be very narrow with many small drops and few large drops, compared with those usually observed at ground level in a continuous rain.

224. Imai, I.

Raindrop Size-Distributions and Z-R Relationships
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 211–218.

> Since 1954, raindrop data have been obtained at MRI, and a wide variation of the Z-R relationship ($80R^{1.5}$ to $700R^{1.5}$) has been found. Several cases are selected from these data, and for each case the size distributions are averaged according to the rainfall rate.

225. Imai, I., Fujiwara, M., Ichimura, I. and Yoshihara, Z.

On the Radar Reflectivity and the Drop Size Distribution of Rain
J Meteorol Res; Vol 7, No 7, p 422–433 (Oct 1955).

Continuous observations of raindrop size distributions were made in the summer of 1954 at three locations about 20 km WNW of the radar site. Automatic raindrop samplers were used, in which a roll of filter paper is unrolled and passed beneath an opening for sampling and then scrolled up round a motor-driven cylinder.

226. Israel, H.

Recent Theories and Experiments on Hail Formation
Umschau (Germany); Vol 53, No 13, p 385–388 (1953).

227. Ito, K., Yano, T. and Hama, K.

Size Distribution, Crystal Form and Falling Velocity of Snowflakes
Kisho Shushi; Vol 31, No 6, p 219–231 (1953).

228. James, W. J.

The Effect of the Weather in Eastern England on the Performance on X Band Ground Radars
Royal Radar Estab., Great Britain, AD-264 418, Tech Note No 655 (Jul 1961).

The known effects of rain, clouds etc. on microwave radiation are combined with the actual weather conditions in Eastern England in order to assess the practical operational effects on X band ground radar equipments.

229. Japan. Nat. Comm. for URSI

"Radio and Troposphere"
Progress in Radio Science in Japan, Chap. 2, Japan. Nat. Comm. for URSI, Tokyo, 1963.

230. Johnson, D. S.

Application of Radar to Cloud Physics Research in Hawaii
Conference on Radio Meteorology, Univ. of Tex., Austin, Tex. (Nov 1953), Sponsor: Univ. of Tex., p VII-2.

Radar reflectivity data compared with drop size distributions obtained at ground with dye treated filter paper show large discrepancies, indicating that coalescence, evaporation, etc. below cloud base are serious factors. Rainfall intensities cannot be calculated accurately from radar reflectivity in Hawaii. Intensity of rainfall vs. liquid water content and vs. radar reflectivity is shown graphically with inclusion of data from Blanchard at Mauna Loa, and Marshall and Palmer.

231. Johnson, J. C.

Meteorological Factors and Their Effects on Microwave Propagation
Hughes Aircraft Co., Culver City, Calif., AD-90 932, Rep No 412 (Aug 1955).

232. Johnson, J. C.

Scattering from a Dielectric Prolate Spheroid
Tufts Coll., Res. Lab. of Radio Electron., Medford, Mass., Rep No 3, Contr AF 19(604)-550 (Feb 1955).

Solutions of the electromagnetic wave equation in prolate spheroidal coordinates are investigated to determine if functions similar to those used by Mie can be constructed. A numerical example of back scattering of the 3.2 cm microwave by a prolate spheroidal ice pellet is presented.

233. Johnson, J. C. and Batter, J. F.

A Raindrop Spectrometer
Tech. Oper. Inc., Burlington, Mass., AD-243 295, Rep No TO-B 60-4; D-188, Contr AF 19(604)-4987 (Mar 1960).

An air-borne raindrop spectrometer is developed using the principle of right angle scattering of light. Analysis of meteorological conditions, instrument configuration, and aircraft speed indicates that the spectrometer is capable of resolving raindrops 0.2 to 5 mm diameter to within a precision of ±8% while maintaining a counting rate of at least 100 drops per second.

234. Johnson, R. M.

The Effects of Stability on Drop Size Distributions
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 286–291.

An attempt to reduce the variance occurring in rainfall rate-radar reflectivity relationships was investigated using stability as a criterion. Rainfall rate-radar reflectivity relationships were computed and the results are discussed. Highest values were found among conditions of moderate stability while lowest values occurred under stable conditions.

235. Jones, D. M. A.

Rainfall Dropsize Distribution and Radar Reflectivity
Ill. State Water Surv., Univ. of Ill., Urbana, Ill., AD-101 779, Res Rep No 6, Signal Corps. Contr DA-36-039-SC-64723 (Apr 1956).

Data on raindrop-size distribution in various parts of the world are correlated with appropriate radar parameters in order to improve the capability of radar in measuring surface rainfall intensities for Army applications such as radioactive rainout prediction, trafficability, and communications.

236. Jones, D. M. A.

Shapes of Raindrops
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 1–7.

A method of measuring raindrops 2.0 mm and larger in three dimensions is described. The results of measurements made on raindrops photographed during 1956 are described.

237. Jones, D. M. A.

3-cm and 10-cm Wavelength Radiation Back Scatter from Rain
5th Weather Radar Conference, Asbury Park, N. J. (sep 1955), Sponsor: U.S. Army Signal Corps, p 281–285.

See Abstract No. 235.

238. Jones, D. M. A. and Dean, L. A.

Some Observations from Photographs of Falling Raindrops
Conference on Radio Meteorology, Univ. of Tex., Austin, Tex. (Nov 1953), Sponsor: Univ. of Tex., p VIII-2.

See Abstract No. 235.

239. Jones, D. M. A. and Mueller, E. A.

Z-R Relationships from Drop Size Data
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 498–504.

See Abstract No. 235.

240. Jones, R. F.

The Occurrence of Raindrops and Hail of Diameter 2 mm or Greater in the Atmosphere
Aeronaut. Res. Counc., Great Britain, Rep No ARC 20,765 (Feb 1959).

Presents a preliminary assessment of the frequency with which the meteorological conditions will be encountered which will lead to greater damage of the forward-facing parts of aircraft due to impact of raindrops and hail.

241. Jones, R. F.

Relation between Radar Echoes from Cumulus and Cumulonimbus Clouds and the Turbulence within These Clouds
Gr. Brit. Air Ministry, Meteorol. Res. Comm., England, Rep No MRP 484 (Apr 1949).

It has been said that radar echoes are useful in locating the area within Cu-clouds where the largest size drops are (probably the areas of greatest updrafts, severe turbulence) but the problem becomes how to distinguish areas of greatest turbulence in the absence of large drops.

242. Jones, R. F.

The Temperatures at the Tops of Radar Echoes Associated with Various Cloud Systems
Quart J Roy Meteorol Soc; Vol 76, p 312–330 (Jul 1950).

Produces evidence to support the belief that temperatures at the tops of weather echoes are an indication of the relative strengths of the vertical currents within the echoes. Two types of weather echo are indicated according as the vertical currents are strong or weak, giving support to a theory for two different methods for the production of water drops of raindrop size in the atmosphere.

243. Jones, R. F.

Water and Ice in the Atmosphere
J Roy Aeronaut Soc; Vol 63, No 584, p 465–473 (Aug 1959).

The discussion covers the characteristics of water in the liquid form, super-cooled water, size-distribution of water droplets, the water content of super-cooled clouds, ice crystals, hail and total ice and water content of some tropical clouds as well as raindrops.

244. Joss, J. and List, R.

Radar Reflection from Ice-Water Mixture
Z Angew Math Phys; Vol 14, No 4, p 376–380 (Jul 1963).

Experiments with radar of wavelength of 5.05 cm showed that the back-scattering of a spherical ice particle with a diameter of around 2 cm, covered with a shell of spongy ice of a thickness of 1.9 mm and a liquid water content of 25%, is higher than that of an equal sphere of water. But as soon as the total liquid water content was significantly lower, the back-scattering was even lower than the radar echo of a similar ice sphere.

245. aufm Kampe, H. J. and Weickmann, H. K.

Particle Size Distribution in Different Types of Clouds
3rd Weather Radar Conference, McGill Univ., Montreal, Can. (Sep 1952), Sponsor: McGill Univ., p B9–B12.

Cloud spectra collected in different types of clouds are presented.

246. Katz, I.

A Momentum Disdrometer for Measuring Raindrop Size from Aircraft
Bull Am Meteorol Soc; Vol 33, No 9, p 365–368 (Nov 1952).

There exists a need to measure raindrop distributions in storms being investigated by radar. A new air-borne instrument for such measurements has been developed which measures simultaneously the droplet size and the total liquid water.

247. Keily, D. P.

Measurement of Drop-Size Distribution and Liquid Water Content in Natural Clouds
Mass. Inst. of Tech., Cambridge, Mass., AD-257 564, Final Rep, Contr AF 19(640)-3050 (Jul 1960).

A previously developed electric cloud drop probe was reconstructed and extensively flown in a private aircraft.

248. Keily, D. P.

Measurement of Drop Size Distribution and Liquid Water Content in Natural Clouds
Mass. Inst. of Tech., Cambridge, Mass., AD-604 339, Final Rep, Contr AF 19(628)-259 (Feb 1964).

Cloud drops striking a charged metal target are shown to produce an electric pulse whose amplitude is closely proportional to the droplet surface area.

249. Kelkar, V. N.

Size Distribution of Raindrops, Part 1
Indian J Meteorol Geophys; Vol 10, No 2, p 125–136 (Apr 1959).

Results of measurements of the size distribution of raindrops made at Poona during the months of August, September and October 1956, are reported in the form of a table showing the number of drops received at the ground level per m^2 per sec for various ranges of diameter at 0.25 mm interval, for different intensities of precipitation ranging from 0 to 40 mm hr^{-1}. Average values have been calculated and presented in the form of a similar table.

250. Kelkar, V. N.

Size Distribution of Raindrops, Part 2
Indian J Meteorol Geophys; Vol 11, No 4, p 323–330 (Oct 1960).

Average values of the number of raindrops per m^3 of air grouped according to diameters, are given in the form of a table for various average values of precipitation rates ranging from 0.20 mm/hr. The distribution of raindrops amongst different diameter groups has been shown in the form of histograms for six different values of the rate of precipitation.

251. Kelkar, V. N.

Size Distribution of Raindrops, Part 3
Indian J Meteorol Geophys; Vol 12, No 4, p 553–559 (Oct 1961).

Average values of liquid water in mm^3 of raindrops of different diameter groups per m^3 of air are given in the form of a table, for 21 different intensities of precipitation. Several drop-size distribution parameters have been worked out and their variation with the intensity of precipitation represented by formulas, wherever possible.

252. Kelkar, V. N.

Size Distribution of Raindrops, Part 4
Indian J Meteorol Geophys; Vol 13, No 2, p 173–182 (Apr 1962).

Diameter spectra of raindrops for identical intensities of precipitation at different stages of a rain period are illustrated and discussed. Diameter spectra of raindrops at different altitudes from the ground level to the cloud base level at different stages of a rain period are illustrated.

253. Kerker, M.

ICES Electromagnetic Scattering
Pergamon Press, New York, 1963.

254. Kerker, M. and Hitschfeld, W.

Effect of Particle Shape and Secondary Scattering on Microwave Reflections from Clouds and Precipitation
Geophys. Res. Div., McGill Univ., Montreal, Can., Rep No MW-1 (1951).

255. Kerker, M., Langleben, P. and Gunn, K. L. S.

Scattering of Microwaves by a Melting Spherical Ice Particle
J Meteorol; Vol 8, p 424 (Dec 1951).

Back scattering of 10 cm radar from a melting ice sphere of radius 0.2 cm is calculated by the theory of Aden and Kerker.

256. Kerr, D. E.

Propagation of Short Radio Waves
Mass. Inst. of Tech., Radiat. Lab. Series, Vol 13, McGraw-Hill, New York, 1951.

Contains a comprehensive discussion of Mie scattering theory and attenuation and scattering by precipitation.

257. Kessler, E.

Weather Radar Technique Development
Travelers Res. Center, Inc., Hartford, Conn., AD-433 912, Rep No 7457 113, Contr Cwb10709 (Feb 1964).

Quantitative data collected with the WSR-57 radar at Atlantic City from five rainstorms and two snowstorms are compared with precipitation data from 60 recording rain gages within 100 mi of the radar. Reflectivity measurements provide only coarse estimates of point rainfall intensity.

258. Kessler, E. and Russo, J. A.

Statistical Properties of Weather Radar Echoes
10th Weather Radar Conference, Washington, D.C. (Apr 1963), Sponsor: Am. Meteorol. Soc., p 25–38.

259. King, M. and Kainer, S.

Some Parameters of a Laser-Type Beyond-the-Horizon Communication Link
IEEE Proc; Vol 53, No 2, p 137–141 (Feb 1965).

Discusses beyond-the-horizon propagation of laser beams by means of scattering from clouds and hazes as applied to communication systems.

260. Kiryukhin, B. V. and Sulakvelidze, G. K.

The Mechanism of Hail and Shower Formation with Variation in the Velocity of Ascending Currents in Clouds Taken into Account
Tr El'brusskaya Vysokogornaya Ekspeditsiya; No 2(5), p 169–174 (1961); ATS-32P64R.

261. Klinger, H.H.

Generation, Propagation and Application of Millimetre Waves
Das Electron; Vol 2, No 10, p 213–214 (Oct 1948).

Propagation of millimetre wave is characterized by scattering-absorption (scattering and refraction by water drops, absorption by water vapor and oxygen) increasing proportional with distance of transmission and reciprocal proportional to the fourth power of the wave length. Propagation experiments with 6 mm waves shows that in a nonturbulent atmosphere, transmission can be made over 30 km distance.

262. Knechtel, K.B.

A Study of Radar Echo Patterns Related to Mesoscale Network Observations and Topography
M.S. Thesis, Oreg. State Univ., Corvallis, Oreg., AD-441 022 (Jun 1964).

This investigation studies the relationship of the reflectivity in the radar beam depicted by the radar echo patterns to the computed reflectivity at surface observing stations under the radar beam. Drop size distributions at stations in the Oregon State University Mesometeorological Network during the storm period of 27–30 March 1963 provided data for computation of the radar reflectivity at the surface.

263. Kobayashi, T.

Measurement of Raindrop Size by Means of Photographic Paper Treated with $CoCl_2$
J Meteorol Soc Japan; Ser 2, Vol 33, No 5, p 217–219 (Nov 1955).

Size distribution curves are shown for various rainfall rates.

264. Kodaira, N.

Quantitative Mapping of Radar Weather Signals
Weather Radar Res., Mass. Inst. of Tech., Cambridge, Mass., AD-228 154, Rep No 30, Contr DA 36-039-sc-75030 (Jun 1959).

Instrumentation is described which (1) averages the rapidly fluctuating radar video signals from weather, (2) applies an appropriate range correction to the signals, and (3) displays them on a PPI screen in the form of iso-echo contours.

265. Kodaira, N.

Radar Performance of the Precipitation Echoes Employing a Logarithmic I. F. Amplifier and an Averaging Device
Papers Meteorol Geophys (Japan); Vol 10, No 2, p 74–84 (Dec 1959).

The random fluctuations of the weather signals about the average values limit the accuracy of the information obtained from the signals.

266. Kodaira, N.

Radar Rainfall Area Integrator Correcting the Areas of Path Attenuation
Papers Meteorol Geophys (Japan); Vol 6, No 1, p 1–4 (May 1955).

A device for producing a display of integrated radar echo intensity is described.

267. Kostarev, V.V.

Radar Measurement of the Water Content of Clouds
Tr Tsentr Aerolog Observ; No 36, p 31–36 (1961); ATS-32Q68R.

268. Kotov, N.F.

Determination of the Radar Characteristic of the Thunder State of Rainstorms
Tr Gl Geofiz Observ; No 120, p 27–36 (1961); ATS-03N58R.

269. Kotov, N. F.

Radar Characteristics of Showers and Thunderstorms
Tr Gl Geofiz Observ; Vol 102, p 63–93 (1960).

270. Kotov, N. F. and Zhui-Tszyun, K.

Some Results of Radar Studies on the Motions of Rainstorm and Thunderstorm Cells
Tr Gl Geofiz Observ; No 120, p 45–51 (1961); ATS-05N58R.

271. Krasnogorshaya, N. V.

A Photoelectric Method of Investigating the Particle Size Distribution of Precipitation
Izv Akad Nauk SSSR, Ser Geofiz; No 6, p 527–533 (1955);
see also: Izv Akad Nauk SSSR, No 5, p 86–91 (1952).

The photoelectric method for the measurement of the dimensions of moving and resting particles is tested under laboratory conditions.

272. Krustanov, L.

A Case of the Growth of Cloud Droplets by Coalescence
Izv Bulgar Akad Nauk, Ser Fiz; Vol 1, p 196–201 (1950).

273. Kumai, M. and Higuchi, K.

Measurement of the Mass and Number of Falling Crystals in the Atmosphere
J Meteorol Soc Japan; No 3, p 69–76 (1954).

274. Labrum, N. R.

The Scattering of Radio Waves by Meteorological Particles
J Appl Phys; Vol 23, p 1324–1330 (Dec 1952).

Scattering by clouds of small spheroidal obstacles is considered from a theoretical standpoint. Numerical data are obtained for the case of clouds composed of partly melted ice particles.

275. Lamb, J. and Turney, A.

The Dielectric Properties of Water at 1.25 cm Wavelength
Phys Soc London Proc; Vol B62, No 4, p 272 (Apr 1949).

276. Landsberg, H. and Neuberger, H.

On the Frequency Distribution of Drop Sizes in a Sleet Storm
Bull Am Meteorol Soc; Vol 19, No 10, p 354–356 (Oct 1938).

277. Lane, J. A. and Saxton, J. A.

Dielectric Dispersion in Pure Polar Liquids at V. H. F. I. Measurements on Water, Methyl and Ethyl Alcohols.
Proc Roy Soc A; Vol 213, No 1114, p 400–408 (Jul 1952).

278. Langille, R. C.

The Scattering of Ten-Centimetre Radio Waves by Rain
J Geophys Res; Vol 55, p 51–52 (Mar 1950).

Reflections of 10 cm waves by rain have been used to obtain distributions of free rain-water by employing a modified height-finding radar equipment.

279. Langille, B. and Gunn, K.
Quantitative Analysis of Vertical Structure in Precipitation
J Meteorol; Vol 5, No 6, p 301–304 (1948).

280. Laws, J. O. and Parson, D. A.

The Relation of Rain Drop Size to Intensity
Am Geophys Union Trans; Vol 24, p 452–460 (Jan 1944).

281. Leach, W.

Convective Cell Bands in the Central and Eastern United States as Observed by Radar
M.S. Thesis, Tex. A & M Coll., College Station, Tex., AD-117 205, Sci Rep No 2, Contr AF 19(604)-1564 (Apr 1957).

Analysis of time-lapse radarscope films reveals that certain types of line storms have a distinctive and characteristic meso- and micro-structure.

282. Lebedev, V. V. and Makirov, A. Ye.

Determination of the Parameters of Particle-Size Distribution
Izv Vysshikh Uchebn Zavedenii, Fiz; No 4, p 60 – 65 (1960). Trans. by Foreign Tech. Div., Wright-Patterson AFB, Ohio, Ad-269 644, Trans No MCL-1259/1 (Aug 1961).

Describes a mathematical device that yields nomograms and which permits the determination of particle-size distribution of suspensions, fogs, clouds, etc., from three measurements of the relative intensity of light scattered at small angles.

283. Lebedeva, N. A.

How Clouds and Precipitation are Formed
Vsesoiuznoe Obshchestvo Po Rasprostraneniiu Politicheskikh i Nauchnykh Znanii, No. 17, Zhanie Publishing House, Moscow, 1955.

284. Legg, T. H.

The Quantitative Display of Radar Weather Patterns on a Scale of Grey
MacDonald Phys. Lab., McGill Univ., Montreal, Can., AD-239 914, Rep No MW-31, Contr AF 19(604)-6617 (Jun 1960).

Equipment was designed which displays successive factors of signal power, corrected in a known way for distance, as equally discernible steps of grey.

285. Levin, L. M.

The Coagulation of Charged Cloud-Droplets and Size Distribution for Cloud Droplets and Raindrops
Dokl Akad Nauk SSSR, Vol 94, No 6, p 1045 – 1048 (1954).

286. Levin, L. M.

Dimension Distribution Function of Cloud and Raindrops
Dokl Akad Nauk SSSR; Vol 94, No 6, p 1045 – 1048 (1954).

Proposes a logarithmically normal distribution function. This distribution law is verified by data collected for rain and cloud drops. Some of the other known distribution functions are shown to be approximations of the logarithmically normal function.

287. Lhermitte, R.

Observation and Study of Precipitation Echoes, Pt. 1. Theoretical and Physical Grounds of Echoes Interpretation
Mem Meteorol Nat; No 46 (1959).

Pt. I concerns scattering and absorption of centimetric waves by hydrometeors, general reflexions on the shape and nature of particles, parameter $p = 2\pi a/\lambda$ (a = radius of the particles and λ = wave length) and its limits, and the dielectric constant. Mie's theory relating to electromagnetic energy scattering through a spherical particle or an ellipsoidal particle is treated in Pt. 2. The application of Mie's theory, in the case of scattering through a partially melting ice-sphere or through complex geometrical shaped particles, is considered. The last two parts deal with the real case of an echo, due to the presence of a large number of particles contributing to the signal by separately scattering the energy.

288. Lhermitte, R.

On a Method Utilizing Radar to Analyze Precipitation
J Sci Meteorol; Vol 3, No 9, p 9–15 (Jan–Mar 1951).

A method of vertical analysis of rain and a microphotometric technique to determine the density of rain from PPI photographs are described.

289. Ligda, M.G.H.

Middle-Latitude Precipitation Patterns as Observed by Radar
Dept. of Oceanogr. and Meteorol., Tex. A & M Univ., College Station, Tex., Proj 131 (Jan 1957).

290. Ligda, M.G.H.

Study of the Synoptic Application of Weather Radar
Tex. A & M Univ., College Station, Tex., AD-98 708, Rep No 56-16F (Jun 1956).

291. Ligda, M.G.H. and Sullivan, J.D.

Photographic Techniques in Radar Meteorology
Phot Sci Eng; Vol 2, p 1–5 (Jun 1958).

Photographic recording techniques have been devised for radar meteorological observations which make possible the detection of transient echoes from lightning discharges, flash-flood-producing storms, and the horizontal distribution of precipitation in different layers of the atmosphere, etc.

292. Lillesaeter, O.

Scattering of Microwaves by Adjacent Water Droplets in Air
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 192.

293. List, R.

Formation and Structure of Hail
Umschau (Germany); Vol 61, No 17, p 526–528 (Sep 1961).

The results of experiments with the hail tunnel on the formation of hail are discussed. A graph based upon experimental data obtained in the hail tunnel shows the percentage of water that is to be found in the initial phase on a spherical hail granule of particular diameter. In the case of hail granules 2 cm in diameter, at an altitude of 9 km (at temperature of −22°) the liquid in the initial phase amounts to 38%.

294. List, R.

Influencing the Growth of a Hailstone
Z Angew Math Phys; Vol 13, No 4, p 393–401 (1962), T-G-189 (AMS).

295. Litvinov, L. V.

A Continuously Operating Gauge of Rainfall Intensity
Izv Akad Nauk SSSR, Ser Geofiz; No 4, p 381–383 (1955).

296. Litvinov, I. V.

Distribution Spectrum of Raindrops Formed from Melting Hail
Izv Akad Nauk SSSR, Ser Geofiz; No 7, p 903–912 (1958).

Presents the results of investigations of the spectral distribution of drops in rains formed by the melting of hail originally developing in clouds. The measurement of the spectral distribution of drops by means of filter paper, the exclusion of the effect of individual hail particles upon the pluviographic measurements of rainfall intensity and a device for measuring the intensity and amount of hail fall are described. The observations in the spectral distribution of rain formed from hail were made during the Elbrus expedition (in the district of the upper Baksan gorge) and in the Alazan Valley (Trana District, Georgian SSR).

297. Litvinov, I. V.

Drop-Size Distribution Function of Liquid Precipitation
Bull Acad Sci USSR, Geophys Ser; No 12, p 1474–1483 (1956).

298. Litvinov, I. V.

The Effect of Riming on a Spectrum of Rain
Izv Akad Nauk SSSR, Ser Geofiz; No 2, p 232–235 (1956).

299. Litvinov, I. V.

Function of the Distribution of Liquid Precipitation Particles
Izv Akad Nauk SSSR, Ser Geofiz; No 6, p 838–839 (Jun 1957).

The spectral distribution of liquid droplets of varying diameter in different types of rain is described by the Poliakov-Shifrin function $\rho = Ad^2 e^{-\gamma d}$ where ρ = density of distribution of droplets of diameter d, A and γ = function of rainfall intensity. This function is satisfactory for describing the distribution of droplets with a diameter greater than 1 mm.

300. Litvinov, I. V.

Method of Measuring the Size Distribution of Snowflakes
Izv Akad Nauk SSSR, Ser Geofiz; No 7, p 1011–1017 (Jul 1959).

With the aid of diagrams the author describes the construction and operation of a device for measuring the size distribution of snowflakes of any type, i.e., individual crystals, grains, etc., in snowfalls. It involves photographing snowfalls.

301. Litvinov, I. V.

On Raindrop Size Distribution
Bull Acad Sci USSR; Geophys Ser, No 1 (1956).

302. Litvinov, I. V.

The Origin of Multilayered Hailstones
Izv Akad Nauk SSSR, Ser Geofiz; No 2, p 277–279 (1958). Trans. by Miller, J., Am. Meteorol. Soc., Boston, Mass., AD-215 678, Contr AF 19(604)-1936 (Oct 1948).

303. Litvinov, I. V.

Spectrum of Rain
Izv Akad Nauk SSSR, Ser Geofiz; No 1, p 114–116 (Jan 1956).

The author investigates the relationship between the spectral distribution of raindrops and rain intensity, using observations made during an expedition to the Elbrus in 1952.

304. Lowan, A.

Tables of Scattering Functions for Spherical Particles
Appl Math Ser No 4, Nat. Bur. Stand., Washington, D.C. (1949).

305. Ludlam, F.H.

The Role of Radar in Rainstorm Forecasting
Imperial Coll. of Sci. and Tech., London, AD-243 477, Tech Sci Note No 3, Contr AF 61(052)-254 (Apr 1960).

The meteorological problems of rainstorm forecasting, and of the essential part played by radar in providing basic data are reviewed.

306. Ludlam, F.H. and Mason, B.J.

Radar and Synoptic Studies of Precipitating Clouds
Cloud Phys. Res. Lab., Imperial Coll. of Sci. and Tech., London, AD-105 382, Rep No 1 (Jan 1956).

307. Ludwig, F.L. and Nagle, R.E.

Cloud Shield and Radar Precipitation Echo Relationships with Satellite Applications
Stanford Res. Inst., Menlo Park, Calif., AD-240 437, Sci Rep No 1, Contr AF 19(604)-5982 (Apr 1960).

Fifteen mid-United States composite radarscope pictures are presented showing radar precipitation echoes, frontal positions, and total cloud cover. These are accompanied by analyses of the low, middle, and high cloud shields. Thirteen other composites from West Coast and Picket Ship pictures are presented.

308. McDonald, J.E.

The Shape and Aerodynamics of Large Raindrops
J Meteorol; Vol 11, No 6, p 478–494 (Dec 1954).

309. McGill Univ.

Precipitation Studies
McGill Univ., Montreal, Can., AD-277 183, Final Rep, Contr AF 19(604)-2065 (Apr 1962); see also: McGill Univ., AD-117 194, Rep No AFCRC TR-57-274, Contr AF 19(122)-47 (Mar 1957).

These reports describe a continuing study of radar meteorology and cloud physics.

310. Maenhout, A.

The Use of Centimeter Waves in Meteorology
Vlaamse Academie voor Wetenschappen, Letteren en Schoøne Kunsten van Belgie. Klasse der Wetenschappen De Toepassing van Cm golven (Symposium), Brussels (8 Nov 1958).

Centimeter wave radars are used to detect distant precipitation, to examine cloud structure and to observe the formation of precipitation. The radar detection of precipitation is based on the scattering of the cm waves by precipitation particles. The average echo power received may be correlated with the precipitation intensity.

311. Magarvey, R.H. and Taylor, B.W.

Apparatus for the Production of Large Water Drops
Rev Sci Instr; Vol 27, No 11, p 944–947 (Nov 1956).

Drop generators are described for the production of streams of drops the equivalent diameters of which are between 0.5 and 20 mm. These generators are based on the principle of the interrupted jet described by Lord Rayleigh.

312. Magono, C.

Investigation of the Size Distribution of Precipitation Elements by the Photographic Paper Method
Nat. Univ., Yokohama, Japan, Sci Reps Sec 1, No. 3, p 41–51 (Mar 1954).

Empirical formulas are derived from the relationships between the areas colored by precipitation elements (on photographic paper) and the actual size of the precipitation element.

313. Magono, C.

Volume Distribution of the Large Precipitation Elements
J Meteorol Soc Japan; Vol 31, No 8, p 286–297 (Aug 1953).

314. Manalo, E. B.

The Distribution of Rainfall in the Philippines
Philippine Geogr J; Vol 4, No 4, p 104–167 (Oct/Nov 1956).

> Monthly means of rainfall are tabulated for well over 400 synoptic and climatological stations of the Philippine Weather Bureau. The records represented vary in length, ranging up to 75 years. Isohyetal maps are constructed for each month and for the year. The characteristics of rainfall distribution in the Philippines are discussed month by month in considerable detail.

315. Markovitch, L. M. and Muchnik, V. M.

Structure of Thunderstorm Showers, According to Data on the Intensity Distribution of Radio-Echoes with Height
UKR Fiz Zh; Vol 5, No 2, p 268–269 (1960); Trans. by Hobson, L. M., Am. Meteorol. Soc., Boston, Mass., AD-258 401, Trans No M-RA-6, Contr AF 19(604)-6113 (Jan 1961).

316. Marshall, J.S., East, T.W.R., Gunn, K.L.S. and Hitschfeld, W.

The Effect of Particle Shape and Composition on Microwave Attenuation and Scattering by Precipitation
IRE Trans Antennas Propagation, No 3, p 180–185 (Aug 1952).

> Ice particles scatter some of the radiation in all directions, but in the cm-wave band they do this without absorbing any of it, since ice is very nearly a perfect dielectric. Water, on the other hand, has considerable dielectric absorption and a large part of the attenuation by rain is due to thermal dissipation.

317. Marshall, J.S. and Gunn, K.

Measurement of Snow Parameter by Radar
J Meteorol; Vol 9, No 5, p 322–327 (Oct 1952).

318. Marshall, J.S., Hitschfeld, W. and Gunn, K.L.S.

"Advances in Radar Weather"
Advances in Geophysics, Landsberg, H.E., Vol 2, p 1–56, Academic Press, New York, 1955.

> The authors present a thorough review of the entire field of radar meteorology as applied to precipitation and storm detection, since the first published literature ca. 1945.

319. Marshall, J.S., Langille, R.C. and Palmer, W. McK.

Measurement of Rainfall by Radar
J Meteorol; Vol 4, No 6, p 186–192 (Dec 1947).

> Variation of rain content with height is moderate and calculable, hence, it might be possible to determine the intensity of rainfall at a distant point with useful accuracy, by radar echoes from this point.

320. Marshall, J.S. and Palmer, W. McK.

The Distribution of Raindrops with Size
J Meteorol; Vol 5, No 4, p 165–166 (Aug 1948).

> Raindrop size measurements (recorded on filter paper) are correlated with radar echoes.

321. Martin, L. A.

An Investigation of the Rainfall Distribution for Selected Stations in North and Central America
M.S. Thesis, Tex. A & M Coll., College Station, Tex., AD-440 998 (May 1964).

A mean rainfall distribution curve was derived from daily precipitation data for the 30-year period 1931 – 1960 for four stations in North and one in Central America. This mean curve was found to fit the monthly rainfall distribution of all stations in North and Central America for all seasons.

322. Mason, B. J.

Production of Rain and Drizzle by Coalescence in Stratiform Clouds
Quart J Roy Meteorol Soc; Vol 78, p 377 – 386 (Jul 1952).

Calculations have been made of the rate at which droplets originating on salt nuclei of given mass grow by both condensation and coalescence with smaller droplets in layer clouds of given uniform updraught, mean temperature, supersaturation and liquid-water content; also of the rate at which the drops falling from the cloud will shrink by evaporation before reaching the ground.

323. Mason, B. J. and Andrews, J. B.

Drop-Size Distributions from Various Types of Rain
Quart J Roy Meteorol Soc; Vol 86, p 346 (Jul 1960).

324. Mason, B. J. and Ramanadham, R.

Modification of the Size Distribution of Falling Rain Drops by Coalescence
Quart J Roy Meteorol Soc; vol 80, no 345, p 388 – 394 (Jul 1954).

Observations with photoelectric spectrometers are on the average represented by Marshall and Palmer's exponential expression, but a sample over several minutes may show marked deviations.

325. Mason, B. J. and Ramanadham, R.

A Photoelectric Raindrop Spectrometer
Quart J Roy Meteorol Soc; Vol 79, p 490 – 495 (Oct 1953).

An instrument which gives a continuous, automatic record of the size distribution of raindrops at ground level is described.

326. Mass. Inst. of Tech.

Radar Meteorology Course Notes, Used in the 1955 Summer Session
Mass. Inst. of Tech., Lectures by Austin, Atlas, Bemis, Stone, Fleisher, Marshall, etc., Radar Meteorology Course Notes, used in the 1955 Summer Session.

The theory of propagation of electromagnetic radiation in the atmosphere, polarization, scattering and absorption by atmosphere and precipitation is presented.

327. Mass. Inst. of Tech.

Weather Radar Research
Dept. of Meteor., Mass. Inst. of Tech., Cambridge, Mass.,
Quart Tech Reps No. 3-4, Contr DA-36-039-sc-42625 (Dec 1953 and Mar 1954).

During the quarter ending Dec. 15 1953, 17 weather situations were observed and results reported. A program was begun for the variable polarization of the radar beam and its effect on precipitation echoes.

328. Mathur, P. N. and Mueller, E. A.

Radar Back Scattering Cross-Sections From Non-Spherical Drops
5th Weather Radar Conference, Asbury Park, N. J. (Sep 1955), Sponsor: U. S. Army Signal Corps, p 269 – 273.

See Abstract No. 235.

329. Meglis, A.J. and Panara, R.

Recent Literature on Radar Meteorology
Meteorol Geoastrophys Abstr; Vol 11, No 8, p 1307 – 1345 (Aug 1960).

Presents a bibliography consisting of 166 references of theoretical and experimental works in the field of radar meteorology.

330. Mehuron, W.O.

Passive Radar Measurements at C-Band Using the Sun as a Noise Source
Microwave J; Vol 5, No 4, p 87 – 94 (Apr 1962).

Discusses the use of microwave radiation from the sun to determine attenuation by precipitation.

331. Meszaros, E. and Wirth, E.

Equations of Raindrop Size Distribution
Idojaras (Budapest); Vol 63, No 4, p 241 – 243 (Jul/Aug 1959).

The first empirical function formulated by Marshall and Palmer in 1948 is shown to adequately describe the distribution in the region of small diameters. Equations of Best, Levin, Muchnik, Poliakova and Shifrin and Litvinov are reviewed and the computed and measured distribution is shown by a diagram.

332. Meszaros, E.

Direct Methods of Determining Water Content of Clouds and Fog
Idojaras (Budapest); Vol 66, No 2, p 110 – 112 (Mar/Apr 1962).

The author gives a short survey of the practical and theoretical methods allowing the computation of the water contents of clouds and fog on the basis of different characteristics.

333. Mézin, M.

Fog
Secretar Gen a l'Aviat Civile, Rev; No 111, p 52 – 54 (Dec 1961).

After reviewing the definitions of fog and freezing fog according to the WMO International Cloud Atlas, the various aspects of fog and the process of visibility decrease in fog are discussed. The author introduced the notion'"veil" and successively deals with fog as seen from the surface and from an air-ship, fog structure, size of the droplets and light diffusion in fog.

334. Michel, H.

Unusual Hailstones
Ciel at Terre; Vol 77, No 7/8, p 293 – 295 (Aug 1961).

On April 20, 1960 between 10 and 11 a.m., the biggest hailstone ever reported in Brussels was recorded. A lump of ice, estimated weight 3 kg, fell on the Citroen Works at Brussels.

335. Mie, G.G.

Beiträge Zur Optik Trüber Medien, Speziell Kolloidaler Metallösungen
Ann Physik; Vol 25, No 3, p 377 – 445 (Mar 1908).

Basic work on scattering by spherical particles.

336. Mikirov, A.E.

Measurement of the Size Spectrum of Cloud and Fog Particles
Izv Akad Nauk SSSR, Ser Geofiz; No 4, p 512 – 515 (1957).

337. Mikirov, A. E.

Photoelectric Method of Investigating the Size Distribution of Precipitation Particles
Bull Acad Sci USSR, Geophys Ser; No 1, p 120–125 (1957).

> A technique and apparatus are described for measuring from airplanes the concentration of raindrops, the size distribution, their charges and the total amount of water in a given volume of air. The apparatus is based upon the use of an index of scattering of drops which increases the sensitivity and excludes completely the daylight background.

338. Millen, S. G., Aldaz, L. and Keily, D. P.

A Brief Survey of Airborne Raindrop Collection Methods
Mass. Inst. of Tech., Cambridge, Mass., AD-160 748, Rep No 4, Contr AF 19(604)-1287 (Jul 1957).

> The general requirements of an airborne instrument for counting and sizing natural raindrops in the size range 200 to 5000 microns diameter are stated.

339. Minervin, V. E.

Water Content of Clouds According to Network Observations
Mezhduvedomstvennaia Konferentsiia po Voprosam Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva, 6th June 1959, p 91–95 (1961).

> The development of the station network in the USSR for studying systematically the water content of clouds is outlined and some of the results obtained on the variation of water content in frontal clouds are summarized. A cross section diagram reveals that in a warm front cloud system two zones of maximum water content are present; one is situated near the frontal surface somewhat above the latter, the other is about 3-4 km above the line of intersection of the frontal surface with the earth.

340. Minervin, V. E. and Shupyatskii, A. B.

Radar Method of Determining the Phase State of Clouds and Precipitations.
Tr Tsentr Aerolog Observ; No 47, p 63–84 (1963); TT-64-21659, p 1–49 (Feb 1964).

341. Mitra, H. and Kulshrestha, S. M.

Radar Observations of Tropical Duststorms
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 56–69.

342. Molokanov, I. V.

Device for Measuring the Water Content of Clouds in the Drop-Forming State and Rains.
Russ. Patent 152106, Appl No 746678/26-10 (Oct 1961), TT-63-23715.

343. Moore, C. B., Vonnegut, E. A., Vrablik, E. A. and McCaig, D. A.

Gushes of Rain and Hail after Lightning
J Atmos Sci; Vol 21, No 6, p 646–665 (Nov 1964).

> Lightning is often followed in the cloud by a rapidly intensifying echo and then by a gust of rain at the ground. An analysis indicates that within 30 seconds after a lightning discharge, the mass of some droplets may increase as much as 100-fold as the result of an electrostatic precipitation effect.

344. Morris, T. R.

Precipitation in Arizona Cumulus as a Function of Cloud Size and Temperature
J Meteorol; Vol 14, p 281–283 (Jun 1957).

345. Muchnik, V. M.

Approximate Evaluation of the Water Content of Cumulus Rain Clouds
Mezhduvedomstvennaia Konferentsiia po Voprosan Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva, 6th, Jun 1959, p 204–209 (Pub. 1961).

The relationship between the amount of precipitation falling from cumulus rain clouds and the amount of moisture within them at the moment of dissolution of the clouds is calculated approximately.

346. Muchnik, V. M.

Detection of Thunderstorms by Radar on the Basis of Data on Maximum Intensity of Rainfall
Meteorol Gidrol; No 10, p 42–43 (1963); TT-63-41238, p 27–30 (Nov 1963).

347. Muchnik, V. M.

The Formation of Large-Drop Shower Thunderstorm Rain
Tr Ukr Nauchn Issled Gidrometeorol Inst, No 4 (1955).

348. Muchnik, V. M.

Height of Radio Echoes from Precipitation
Nauchn. Issled. Gidrometeorol. Inst., Kiev, Ukraine, Rep No 18, p 86–89 (1959).

Radar observations in the centimeter band during thunderstorms have revealed a reflection at an altitude of 8 to 10 km. These reflections may result from the great number of comparatively large ice particles caused by strong rising air currents.

349. Muchnik, V. M.

Measuring the Intensity of Precipitation by Radar
Meteorol Gidrol; No 7, p 50–54 (1958); 61-19230.

The author made an analysis of the relation $Z = \beta R^{\alpha}$ between the reflecting capacity (Z) of precipitation and its intensity (R). Measurements were made of the distribution and size of raindrops at the earth's surface at various geographic locations to determine values for the constants α and β.

350. Muchnik, V. M.

Some Problems in Procedure for Observation of Showers and Thunderstorms
Meteorol Gidrol; No 1, p 46–48 (1955).

351. Muchnik, V. M.

Some Radar Characteristics of Rain Storms and Thunder Storm Cells
Tr Tsentr Aerolog Observ; No 20, p 82–87, 1958.

352. Mueller, E. A.

Attenuation Calculations from Drop Size Distributions
6th Weather Radar Conference, Cambridge, Mass. (Mar 1957), Sponsor: Am. Meteorol. Soc., p 233–236.

Calculations have been performed on Illinois rain drop size distributions obtained by photographic means, to determine the rain attenuation for 3-cm radiation. Initially, four storms were analyzed using Rayleigh's approximation. It was evident that Rayleigh's law greatly underestimated the attenuation. Six storms consisting of 270 min. of observations were analyzed using Mie's scattering theory.

353. Mueller, E. A.

Raindrop Distributions at Miami, Florida
Ill. State Water Surv., Univ. of Ill., Urbana, Ill., Rep No 9-B, Contr DA-36-039-sc-87280 (Jun 1962).

Raindrop size distributions and analyzed data at Miami, Fla., for Aug. 20, 1957 through Aug. 14, 1958, are presented.

354. Mueller, E. A.

Study of the Radar Precipitation Attenuation as Deduced from Drop Size Distributions
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 194.

355. Mueller, E. A.

Uncertainty in Rainfall Measurements by Radar Due to Drop Size Distributions
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 442–445.

Raindrop size distributions obtained by the raindrop camera located at the University of Miami were analyzed to determine the amount of error in rainfall estimate caused by variations in drop size distributions. The relationships between rainfall rate and radar back scattering cross section were then determined for each group according to the fitting criteria.

356. Mueller, E. A.

Study of Intensity of Surface Precipitation using Radar Instrumentation
Ill. State Water Surv., Urbana, Ill., AD-132 120, Quart Tech Rep No 7, Contr DA-36-039-sc-64723 (Mar 1957).

See Abstract No. 235.

357. Mueller, E. A. and Jones, D. M. A.

Drop-Size Distributions in Florida
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 299–305.

358. Mueller, E. A., Stout, G. E. and Ackermann, W. C.

Study of Intensity of Surface Precipitation using Radar Instrumentation
Ill. State Water Surv., Urbana, Ill., AD-204 480, Quart, Tech Rep No 1, Contr DA 36-039-sc-75055 (Jun 1958).

See Abstract No. 235.

359. Mueller, E. A., Stout, G. E. and Johnson, R. M.

Study of Intensity of Surface Precipitation using Radar Instrumentation
Ill. State Water Surv., Urbana, Ill., AD-271 058, Final Rep, Contr DA 36-039-sc-75055 (Sep 1961).

See Abstract No. 235.

360. Mueller, E. A. and Stout, G. E.

Investigation of the Quantitative Determination of Point and Areal Precipitation by Radar Echo Measurements
Ill. State Water Surv., Urbana, Ill., Quart Tech Rep No 2, Contr DA-36-039-sc-87280 (Mar 1962).

See Abstract No. 235.

361. Mueller, E. A. and Sims, A. L.

Investigation of the Quantitative Determination of Point and Areal Precipitation by Radar Echo
Ill. State Water Surv., Urbana, Ill., AD-602 744, Tech Rep No 9, Contr DA 36-039-sc-87280 (Mar 1964).

One minute drop size spectra have been obtained for the sites listed below. Liquid water content has been determined and a frequency of

occurrence of liquid water content is reported. Summary of data collected:

Location	Days of Sample	Samples	Rainfall Rate mm hr^{-1} (max)
Woody Island, Alaska	74	2688	26
Miami, Florida	79	2506	722
Majuro, Marshall Islands	93	2552	270
Corvallis, Oregon	59	1706	26
Bogar, Indonesia	76	1879	282
Champaign, Illinois	36	1126	130
Island Beach, New Jersey	78	2354	155
Coweeta, North Carolina	85	3369	310

362. Nagle, R. E., Blackmer, R. H. and Ligda, M. G. H.

Research Directed toward the Use of Synoptic Radar Observations in the Interpretation of Satellite Cloud Observations
Stanford Res. Inst., Menlo Park, Calif., AD-244 732, Tech Progr Rep No 2, Contr AF 19(604)-5982 (Jun 1960).

Included are the dates and times of fifteen composite radarscope charts that were constructed for simultaneous satellite cloud comparisons.

363. Nakaya, U.

Formation of Snow Crystals
Snow, Ice and Permafrost Res. Estab., Wilmette, Ill., AD-27 515, Rep No 3, (Jan 1954).

364. Nelepets, V. S. and Stepanenko, V. D.

Radar Methods of Meteorological Observations
Radiopokatsionnye Metody Meteoropogicheskikh Nabpyudenii, Leningrad, 1961, FTD-TT-62-1423 (Apr 1963).

Deals with the use of radar methods in meteorology, some general problems in radar, and the theory of radar sounding of atmospheric formations.

365. Neuberger, H.

Notes on Measurement of Raindrop Sizes
Bull Am Meteorol Soc; Vol 23, No 6, p 274–276 (Jun 1942).

366. Neumann, J.

Drop Size and Relative Mass Contributed in Rain
J Meteorol; Vol 8, No 3, p 205–206 (Jun 1951).

It is demonstrated that the maxima of the family of curves for different rain intensities fall on a rectangular hyperbola.

367. Newell, R. E.

Some Radar Observations of Tropospheric Cellular Convection
Mass. Inst. of Tech., Cambridge, Mass., AD-233 832, Res Rep No 33, Contr AF 19(604)-2291 (Nov 1959).

Small-scale cellular convection is a mode of motion whose role in the vertical transport processes in the troposphere is not established. The observation of cell spacing and depth, for cells which do not exceed about 6 km in depth, vary in a manner which is similar to that predicted from the Bénard cell theory of Lord Rayleigh.

368. Newell, R. E., Geotis, S. G., Stone, M. L. and Fleisher, A.

How Round Are Raindrops?
5th Weather Radar Conference, Asbury Park, N.J. (Sep 1955), Sponsor: U.S. Army Signal Corps, p 261-268.

Radar experiments show that particles in the melting layer depart considerably from roundness. Snow also appears nonspherical to the radar. In the melting layer there is evidence that preferred horizontal orientation exists at times while experiments have always shown random orientation in rain.

369. Newell, R. E., Geotis, S. G. and Fleisher, A.

Shape of Rain and Snow at Micro Wavelengths
Dept. of Meteorol., Mass. Inst. of Tech., Cambridge, Mass., Res Rep No 28, Contr DA-36-sc-71136 (Sep 1957).

A technique is described in detail whereby shape and orientation of hydrometeors can be measured. The technique involves the use of 3.2 cm radar whose polarization changes as a function of particle shape and orientation. Results of observations made in showers, rain, snow and the melting layer are reported.

370. Newell, R. E. and Stone, M. L.

On the Application of Weather Radar Observations in the Study of Microwave Attenuation
Lincoln Lab., Mass. Inst. of Tech., Lexington, Mass., to be published in 1966.

371. Niessen, C. W.

Signal Level Quantizer for Weather Radar
B. S. Thesis, Mass. Inst. of Tech., Cambridge, Mass., 1962.

372. Nikandrova, G. T. and Fridman, Iu. S.

Method of Determining the Characteristics of the Droplet Size Distribution in Clouds
Tr Gl Geofiz Observ; No 102, p 58–62 (1960).

The variability of the spectrum of the dimensions of drops in clouds and the determination of what constitutes an adequate number of samples was investigated by mathematical statistical methods applied to data on the distribution of drops for Cirrus Congestus and Stratus clouds.

373. Noel, T. M. and Fleisher, A.

The Linear Predictability of Weather Radar Signals
Weather Radar Res., Mass. Inst. of Tech., Cambridge, Mass., AD-240 293, Res Rep No 34, Contr AF 19(604)-5220 (Jun 1960).

The linear predictability of the plane field of radar signals from weather is studied. The results are a description of (1) the quality of the forecasts and their dependence on time and location, (2) the sources of information, and (3) the eddy structure of precipitation.

374. Nourse, O. and Nicholls, S. G.

Effect of Weather on Performance of an 8 mm Radar
Electron Power; Vol 10, p 342–343 (Oct 1964).

375. Nupen, W.

Selective Annotated Bibliography on Radar as Applied to Meteorology
Meteorol Abstr Bibliogr; Vol 2, No 8, p 680–711 (Aug 1951).

Presents a bibliography of 232 annotated references to material on the application of radar or microwave equipment to observation of meteorological elements.

376. Nupen, W.

An Annotated Bibliography on Radar as Applied to Cloud and Precipitation Physics
Meteorol Abstr Bibliogr; Vol 6, No 7, p 997–1050 (Jul 1955).

267 references relevant to radar meteorology published between 1941 and 1955 are presented.

377. Oguchi, T.

Attenuation of Electromagnetic Wave Due to Rain with Distorted Raindrops
J Radio Res Lab (Japan); Vol 7, p 467–485 (Sep 1960).

The total cross-section, for any material, of a spheroidal particle with small eccentricity is derived by solution of the scattered field expressed as a first-order approximation of drop deformation. The total cross-sections of raindrops by vertically and horizontally-polarized plane waves are computed at 8.6 mm wavelength, and the relation between attenuation and precipitation rate obtained.

378. Oguchi, T.

Statistical Fluctuation of Amplitude and Phase of Radio Signals Passing Through the Rain
J Radio Res Lab (Japan); Vol 9, No 41, p 51–72 (Jan 1962).

379. Ohta, S.

On the Dry and Wet Fog and Size of Their Drops
J Meteorol Soc Japan; Ser 2, Vol 24, p 21–23 (1946).

Types of fog were classified as dry, wet and medium, according to the wetness of the fog. The mutual relation between these types, drop size and wind velocity was studied.

380. Okamura, S.

The Measurement of Attenuation by Rain at 8.6 mm Wave Length
Denki Tsushin Gakkai Zasshi; Vol 45, No 6, p 757–763 (Jun 1962).

381. Okamura, S., Funakawa, K., Uda, H., Kato, J. and Oguchi, T.

Effect of Polarization on the Attenuation by Rain at Millimeter-Wave Length
J Radio Res Lab (Japan); Vol 8, p 73–80 (Mar 1961).

Due to the distortion of raindrops as they fall, it is to be expected that the attenuation of horizontally polarized waves propagating in rain will exceed that of vertically polarized waves. Experiments conducted at a wavelength of 8.6 mm over a 3.5 km path in rainfall of up to 10 mm/hr. with a f.m. -radar system in which the plane of polarization was continuously switched between the vertical and the horizontal have confirmed this expectation.

382. Okamura, S., Funakawa, K., Uda, H., Kato, J. and Oguchi, T.

On the Measurement of Attenuation by Rain at 8.6 mm Wave Length
J Radio Res Lab (Japan); Vol 6, p 255–267 (Apr 1959).

The attenuation by rain at 8.6 mm wavelength was measured by the f.m. radar method. Though the reflecting target was only 400 m distant from the aerial, attenuation could be measured under conditions of showers or typhoons which existed in September, 1958.

383. Orhaug, T.

The Effect of Atmospheric Radiation in the Microwave Region
Pub of Nat Radio Astron Observ; Vol 1, No 14, p 215–249 (Oct 1962).

> Considers sources of fluctuating components in antenna noise temperature due to absorption along the line of sight. Theoretical investigation of atmospheric brightness temperature resulting from the presence of condensed water is presented. The results of observations at 3 and 8 Gc are given. A 1°K variation in brightness temperature may be experienced for as much as 20% of the time at 8 Gc.

384. Orhaug, T.

Fluctuation Component of Atmospheric Noise Temperature
Proc IEEE; Vol 51, No 3, p 477 (Mar 1963).

385. Ouchi, K.

On the Size Distribution of Raindrops, Pt. 1
J Meteorol Soc Japan; Ser 2, Vol 35, p 196–200 (Jun 1957).

> Sizes of about 54,000 raindrops are measured for 249 observation periods of 9 rainfalls by filter paper method. Results are analyzed according to the rainfall intensity of each period.

386. Ouchi, K.

On the Size Distribution of Raindrops, Pt. 2
J Meteorol Soc Japan; Ser 2, Vol 36, No 4, p 156–160 (Aug 1958).

> Sizes of about 167,000 raindrops in 31 rainfalls are measured by the filter paper method. The time-average distributions of raindrops with size during about an hour of each rainfall are examined and classified into four types, according to the degree by which they differ from the equivalent Marshall-Palmer distribution which has an equal rate of rainfall.

387. Packmett, D. S.

Relationships between Radar Precipitation-Echo Patterns Associated with Mid-Western Tornadoes and Their Corresponding Synoptic Meteorological Situations
M. S. Thesis, Tex. A & M Coll., College Station, Tex., AD-214 351 (Jan 1959).

> Recent investigations show that radar precipitation-echo patterns associated with midwestern tornadoes can be classified into types based upon the appearance of the echoes displayed on a radar PPI oscilloscope photograph.

388. Panchev, S.

Evaporation of Spherical Drops of Water Falling Freely through the Atmosphere
C. R. Acad Bulg Sci; Vol 10, No 5, p 355–358 (Sep-Oct 1957).

> Formulates and solves the equation of motion of drops. The velocity of the drops is proportional to the square root of their radius.

389. Parkash, S.

Annotated Bibliography on Radar Meteorology
Meteorol Geoastrophys Abst; Vol 14, No 2, p 523–582 (Feb 1963).

390. Pearson, J. E. and Martin, G. E.

An Evaluation of Raindrop Sizing and Counting Instruments
Ill. State Water Surv., Urbana, Ill., AD-146 773, Sci Rep No 1,
Contr AF 19(604)-1900 (Nov 1957).

> A study was made of the merits of devices and techniques used to determine size-distribution of raindrops and cloud droplets.

391. Perlat, A. and Voge, J.

Attenuation of Centimetre and Millimetre Waves in the Atmosphere
Ann Télécommun; Vol 8, p 395–405 (Dec 1953).

Reviews earlier work, considering the attenuating influences of various meteorological parameters – rain, storm, fog, etc. – and of atmospheric oxygen and water vapour. Following a statistical study of meteorological data for France and North Africa, calculations are made of atmospheric attenuation on a given trajectory for various percentages of time.

392. Phillips, W.

Interpretation of Precipitation Echoes Observed by Conard Radar
U.S. Air Force, 3rd Air Weather Group, Ent AFB, Colorado, Tech Paper No 4 (Aug 1955).

Theory, equipment and interpretation of various types of echoes and anomalous propagation conditions are treated systematically with numerous radar weather photos and considerable data.

393. Phys. Soc. of London and Roy. Meteorol. Soc.

Meteorological Factors in Radio-Wave Propagation
Conference on Meteorological Factors in Radio-Wave Propagation, The Royal Inst., London (Apr 1946), Sponsor: Phys. Soc. of London.

Included are 21 papers describing various investigations concerned with the effect of the meteorological conditions of the lower atmosphere on very short radio waves transmitted through it.

394. Planck, V. G., Atlas, D. and Paulsen, W. H.

The Nature and Detectability of Clouds and Precipitation as Determined by 1.25 cm Radar
J Meteorol; Vol 12, No 4, p 358–378 (Aug 1955).

395. Planck, V. G., Atlas, D. and Paulsen, W. H.

Preliminary Survey of Cloud and Precipitation Detection at 1.25 cm
3rd Weather Radar Conference, McGill Univ., Montreal, Can. (Sep 1952), Sponsor: Am. Meteorol. Soc., p B13–B20a.

396. Podell, R.

Some Radar Studies of Rain Attenuation and the Relation between Precipitation Rate and Reflected Power
B. A. Thesis, Mass. Inst. of Tech., Cambridge, Mass., 1949.

Attempts to determine rain attenuation at 3 cm by comparisons between maximum range, as observed on the 3 cm AN/TPS-10A radar, and reflected power measurements on the 10 cm SCR-615-P radar.

397. Probert-Jones, J. R.

The Analysis of Doppler Radar Echoes from Precipitation
8th Weather Radar Conference, San Francisco, Calif. (Apr 1960), Sponsor: Am. Meteorol. Soc., p 347–354.

Two sets of records obtained from the verticle pointing Doppler radar during the passage of warm-frontal rain areas have been analyzed and drop size distributions computed.

398. Probert-Jones, J. R.

Distortion of Cumulonimbus Precipitation Observed by Radar
Imperial Coll. of Sci. and Tech., Dept of Meteorol., London, Tech Note No 13, Contr AF 61(052)-254 (Nov 1963).

399. Probert-Jones, J. R.

"Surface Waves Associated with the Back-Scattering of Microwave Radiation by Large Ice Spheres"
Electromagnetic Scattering, p 237 – 250, Pergamon Press, Oxford, 1963.

Gives a physical interpretation of the calculations by Herman and Battan in terms of a main back-scattering component due to the "glory" ray and a number of other components interfering with it, due to surface waves formed from incident waves at grazing incidence, with different numbers of cuts through the sphere and of times of travel round it.

400. Ramanadham, R., Mohana Rao, K. M. and Nagamuneswara Rao, K.

Raindrop Spectrum Analysis
J Sci Ind Res (India); Vol 21B, No 5, p 207 – 209 (May 1962).

From an analysis of the data obtained from shower and layer types of precipitation, using the filter-paper technique, the empirical formula suggested by Best to represent the variation of drop size distribution with intensity of rainfall was modified by introducing a new parameter, the spectral width (which is defined as the difference in the diameters of the maximum and minimum size of drops observed), to take account of the distribution of the limits of the diameters of the raindrops.

401. Ramanadham, R. and Vidyavathi, K.

Size Distribution of Raindrops from Layer Type Clouds in Tropics
J Meteorol Soc Japan; Ser 2, Vol 35, No 4, p 221 – 226 (Aug 1957).

A preliminary study of the size distribution of raindrops from layer type precipitation in the tropics has been made. The large deviations in the size distribution which have been ignored by past workers, in the attempt to develop an empirical relationship between the dropsize and intensity of rain, have been examined.

402. Ricupero, P. C.

Weather Echo Quantizer
M. S. Thesis, Mass. Inst. of Tech., Cambridge, Mass. (1960).

403. Rigby, E. C., Marshall, J. S. and Hitschfeld, W.

The Development of the Size Distribution of Raindrops During Their Fall
J Meteorol; Vol 11, No 5, p 362 – 372 (Oct 1954).

Numerical methods are used to study the changes in the distribution of raindrops with size and in the radar echo as rain falls. Changes brought about by collisions among the drops by accretion of cloud and by evaporation are considered. The distribution assumed aloft is that actually observed at the ground.

404. Rigby, E. C. and Marshall, J. S.

Modification of Rain with Distance Fallen
MacDonald Phys. Lab., McGill Univ., Montreal, Ca., Rep No MW-3, Contr AF 19(122)-217 (Jan 1952).

The modification of size distribution is investigated in a detailed manner under three headings: (1) accretion of clouds by raindrops, (2) coalescence between raindrops and (3) evaporation of raindrops.

405. Rink, J.

Use of Radar Technology in Meteorology
Meteorol Hydrol Dienst, Abhandl; Vol 9, No 65 (1962); 63-13312.

406. Robertson, S. D. and King, A. P.

The Effect from Rain upon the Propagation of Waves in the One- and Three-Centimeters Regions
IRE Proc; Vol 34, No 4, p 175 – 180 (Apr 1946).

Correlation between rainfall rate and attenuation measurements is shown to be good over a short path.

407. Robinson, N. P.

The Propagation of 8 mms. Wavelength Radiation through Rain, Snow, Hail and Fog
Telecommun. Res. Estab., Great Britain, AD-12 573, TRE Tech Note No 191 (Apr 1953).

Tests showed that the attenuation caused by rain was nearly proportional to the precipitation rate, and was 0.26 db/km/mm/hr for the range of precipitation rates from 1 to 11 mm/hr. The measured intensity of radiation scattered back by rain agreed well with theoretical conditions. Moist snow produced attenuation 2.5 times greater than rain of the same precipitation rate. The echo intensity returned from dry snow was 14 to 19 db less than that of the melting band or radar bright band composed of melting snow. The echo intensity of rain was 2 to 8 db less than that from the melting band producing the rain.

408. Rogers, C. W. C.

Note on the Vertical Variations in Radar Reflectivity
Weather Radar Res., Mass. Inst. of Tech., Cambridge, Mass., Rep No 1, Contr AF 19(640)-2291 (Jun 1959).

This paper presents the results of a survey of the frequency of occurrence of detectable increases or decreases in radar reflectivity with height in the lower levels of the atmosphere. The relationship between variations in reflectivity with height and the vertical velocity profiles is discussed.

409. Rogers, R. R.

An Extension of the Z-R Relation for Doppler Radar
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 158.

410. Rogers, R. R. and Pilie, R. J.

Radar Measurements of Drop Size Distribution
J Atmos Sci; Vol 19, No 6, p 503 – 506 (Nov 1962).

A Doppler radar system can be used to estimate the distribution of drop sizes in atmospheric rain.

411. Rosenblum, E. S.

Atmospheric Absorption of 10-400 kMcps Radiation: Summary and Bibliography to 1960
Lincoln Lab., Mass. Inst. of Tech., Lexington, Mass., AD-242 598, Rep No 82G-0021, Contr AF 19(604)-5200 (Aug 1960).

The presently available data on atmospheric absorption is summarized, and the limitations of these data are explained. Emphasis is placed on absorption by normal molecular oxygen and water vapor; other contributing factors are considered only incidentally.

412. Roy, A. K. and Srivastava, R. C.

A Theoretical Study of Progressive Developments in Raindrop Size Distribution and Other Characteristics in Rain Showers from "Warm" Convective Type Clouds
Indian J Meteorol Geophys; Vol 9, No 3, p 213–224 (Jul 1958).

A study, on a theoretical basis, of the expected size distribution of raindrops, and rainfall intensity at various phases of rain showers from an overhead large cumulus cloud of "warm" type has been made, assuming that each raindrop is the result of growth on a "giant" sea-salt nucleus, and that droplet growth beyond a certain size is due mainly to coalescence following collisions between cloud droplets.

413. Ryde, J. W.

The Attenuation and Radar Echoes Produced at Centimetre Wave-Lengths by Various Meteorological Phenomena
Conference on Meteorological Factors in Radio-Wave Propagation, The Royal Inst., London (Apr 1946), Sponsor: Phys. Soc. of London, p 169–188.

414. Ryde, J. W. and Ryde, D.

Attenuation of Centimetre and Millimetre Waves by Rain, Hail, Fog and Clouds
Gen. Elec. Corp., Res. Lab., London, Rep No 8670 (1945).

415. Sal'man, Ye. M.

Method of Radar Investigation of the Structure of Cumulonimbus Clouds
Tr Gl Geofiz Observ; No 82, p 68ff (1958); 61-23298.

416. Sal'man, Ye. M.

Problem of the Optimum Radar Wave-Length for the Detection of Cloud Systems and Precipitation
Tr Gl Geofiz Observ; No 102, p 94–103 (1960); ATS-83M46R.

417. Sal'man Ye. M.

Radar Study of Shower and Thunderstorm Structure
Tr Gl Geofiz Observ; No 72 (1957).

418. Saxton, D. S.

Lectures on the Scattering of Light
Dept. of Meteorol., Univ. of Calif., Los Angeles, Calif., Rep No 9, Contr AF 19(122)-233 (Mar 1955).

The exact (Mie) theory for the scattering of a plane wave by a dielectric sphere is presented in more detail and using somewhat more modern methods than is customary in the literature.

419. Saxton, D. S., Sekera, Z. and Deirmendjian, D.

Approximation of Light Scattering by Large Dielectric Spheres
Dept. of Meteorol., Univ. of Calif., Los Angeles, Calif., Rep No 3, Contr AF 19(604)-2429 (Jun 1960).

The approximate expression for the amplitude of the electric vector of the scattered radiation by a large dielectric sphere is derived from an exact integral solution of Maxwell equations. The unknown electric and magnetic field vectors in the interior of the dielectric sphere are approximated by the assumption of rectilinear propagation of the incident wave through the sphere.

420. Saxton, J. A.

The Anomalous Dispersion of Water at Very High Radio Frequencies. Part II – Relation of Experimental Observations to Theory
Conference on Meteorological Factors in Radio-Wave Propagation, The Royal Inst., London (Apr 1946), Sponsor: Phys. Soc. of London, p 293–306.

421. Saxton, J. A.

The Anomalous Dispersion of Water at Very High Radio Frequencies. Part III - The Dipole Relaxation Time and Its Relation to the Viscosity
Conference on Meteorological Factors in Radio-Wave Propagation, The Royal Inst., London (Apr 1946), Sponsor: Phys. Soc. of London, p 306 – 316.

422. Saxton, J. A.

Dielectric Dispersion in Pure Polar Liquids at Very High Radio-Frequencies. II – Relation of Experimental Results to Theory
Roy Soc Proc; Sec A, Vol 213, No 1115, p 473 – 494 (Jul 1952).

423. Saxton, J. A.

The Dielectric Properties of Water Vapor at Very High Radio Frequencies
Conference on Meteorological Factors in Radio-Wave Propagation, The Royal Inst., London (Apr 1946), Sponsor: Phys. Soc. of London, p 215 – 238.

424. Saxton, J. A.

Reflection Coefficient of Snow and Ice at V. H. F.
Wireless Eng; Vol 27, p 17 – 25 (Jan 1950).

A review is given of the nature and composition of snow, and of the experimental knowledge of the dielectric properties of ice at v.h.f. From this information an estimate has been made of the dielectric properties of snow.

425. Schramm, C. K.

The Effect of Water and Ice on Microwave Transmission through Radomes
Components and Syst. Lab., Wright-Patterson A.F.B., Ohio, AD-9 153, Tech Note No WCLC 53-2 (Feb 1953).

426. Schuetz, J., Semonin, R. G. and Mueller, E. A.

Study of Intensity of Surface Precipitation using Radar Instrumentation
Ill. State Water Surv., Urbana, Ill., AD-112 491, Rep No 4 (Jun 1956).

427. Shishkin, N. S.

The Effect of Size Distribution of Cloud Particles on the Size of Rain Drops
Tr Gl Geofiz Observ; No 54, p 78 – 80 (1955).

428. Shishkin, N. S.

The Size of Rain Drops
Dokl Akad Nauk SSSR; Vol 90, No 2, p 171 – 174 (May 1953).

Discusses the theoretical dependence of raindrop sizes on the velocity of ascending currents in clouds consisting of water droplets, assuming the rate of growth is determined by condensation and gravitational coagulation.

429. Shupiatskii, A. B.

Measurement of Average Drop Size and Water Content in Intense Rain by Means of Radar
Tr Tsentr Aerolog Observ; No 20, p 58 – 66 (1958).

This study is focused on water drops in rain and their effect on microwaves. The theory of dispersion and absorption of microwaves by the meteorological particles is discussed and analyzed mathematically and examples with assumed numerical values are given.

430. Shupiatskii, A. B.

Radar Scattering by Non-Spherical Particles
Tr Tsentr Aerolog Observ; No 30, p 39 – 52 (1959); TT-62-23702.

431. Sims, A. L.

Case Studies of the Areal Variations in Raindrop Size Distributions
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol.Soc., p 162.

432. Sims, A. L. and Mueller, E. A.

Investigation of the Quantitative Determination of Point and Areal Precipitation by Radar Echo Measurements
Ill. State Water Surv., Urbana, Ill., AD-602 744, Tech Rep No 9, Contr DA 36-039-sc-87280 (Mar 1964).

See Abstract No. 235.

433. Sivaraman, K. R. and Sivaramakrishnan, M. V.

Modification of the Size Distribution of Raindrops with Distance Fallen
Indian J Meteorol Geophys; Vol 13, Special No, p 17 – 20 (Mar 1962).

The modification of the size distribution of raindrops from stratiform clouds during their fall due to coalescence, accretion and evaporation is investigated. It is seen that under a steady state, i.e., when a constant flux of raindrops is crossing the melting level, the size distribution at melting level is considerably modified as the drops reach the ground.

434. Sivaramakrishnan, M. V.

The Relation between Raindrop Size Distribution Rate of Rainfall and the Electrical Charge Carried Down by Rain in the Tropics
Indian J Meteorol Geophys; Vol 11, No 3, p 258 – 268 (Jul 1960).

It is shown that a knowledge of rain current is necessary to find the variation in drop size distribution between two rain measurements, especially when both the liquid water content and intensity of rainfall are the same in both cases.

435. Smith, E. J.

Observations of Rain from Non-Freezing Clouds
Quart J Roy Meteorol Soc; Vol 77, No 331, p 33 – 43 (Jan 1951).

436. Smith, G. D.

The Use of Composite Radar Photographs in Synoptic Weather Analysis
M.S. Thesis, Tex. A & M Coll., College Station, Tex., AD-133 687, Sci Rep No 3, Contr AF 19(640)-1564 (Aug 1957).

An attempt was made to demonstrate the value of simultaneous radar observation by several PPI radar-scopes of a large portion of a storm, when resolved into a single composite radar photograph, and to derive techniques for including the radar data into the analysis.

437. Smith, L. G.

New Method to Measure Raindrop Size
Ill. State Water Surv., Urbana, Ill., Bull No 41, p 299 (1952).

Describes a method worked out at Cambridge, England, for measuring size of raindrops by change in capacity of a parallel plate condenser when a drop falls between the plates.

438. Smith, P. L.

Scattering of Microwaves by Cloud Droplets
11th Weather Radar Conference, Boulder, Colo. (Sep 1964), Sponsor: Am. Meteorol. Soc., p 202.

439. Spilhaus, A.

Drop Size, Intensity, and Radar Echo of Rain
J Meteorol; Vol 5, No 4, p 161–164 (Aug 1948).

Describes an experimental set-up utilizing a simple relation between terminal speed and size of raindrops and an empirical drop-size distribution.

440. Srivastava, R. C. and Kapoor, R. K.

Drop Size Distribution and Liquid Water in a Winter Fog at Delhi
Indian J Meteorol Geophys; Vol 11, No 2, p 157–162 (Apr 1960).

Observations made on 10 Dec. 1958 of persistent drifting fog in Delhi are reported and the size distributions of fog droplets and their variations with aging of the fog are discussed. The technique of measurement of fog droplets is described and the details of the measurement process are tabulated.

441. Stephens, J. J.

On the Applicability of Rayleigh Scattering in Radar Meteorology
J Appl Meteorol; Vol 3, No 2, p 211–212 (Apr 1964).

Demonstrates the error incurred at two wavelengths through the use of the Rayleigh approximation.

442. Stephens, J. J.

Radar Characteristics of an Exponential Dropsize Distribution with Application to a Dual Frequency System
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., NSF Grant No NSF G22115 (Oct 1962).

443. Stephens, J. J.

Radar Cross Sections for Water and Ice Spheres
J Meteorol; Vol 18, No 3, p 348–359 (Jun 1961).

The validity of the Rayleigh approximation is shown as a function of drop diameter, and the temperature dependence is shown for a wavelength of 3.2 cm.

444. Stout, G. E. and Ackermann, W. C.

Study as to Merits of Various Rapid Raindrop Counting and Sorting Techniques
Ill. State Water Surv., Urbana, Ill., AD-152 632, Rep No AFCRC TR-58-255, Contr AF 19(604)-1900 (Mar 1958).

A literature search was made to evaluate known instruments, designs, and methods of counting rain and drizzle drops according to their sizes.

445. Stout, G. E., Blackmer, R. H. and Wilk, K. E.

"Hail Studies in Illinois Relating to Cloud Physics"
Physics of Precipitation, Monogr No 5, p 369–383, Am. Geophys. Union (1960).

Three independent hail studies during the past year have provided considerable basic knowledge concerning Illinois hailstorms. One hundred eighty days with hail which caused damage to crops during 1953–1957 have been studied.

446. Stout, G. E. and Farnsworth, G. W.

Rainfall-Radar Studies of 1951
Meteorol. Lab., Univ. of Ill., Urbana, Ill., AD-22 620, Rep No 19, Contr DA 36-039-sc-42446 (May 1953).

447. Stout, G. E. and Hiser, H. W.

Radar Scope Interpretations of Wind, Hail, and Heavy Rain Storms between May 27 and June 8, 1954
Bull Am Meteorol Soc; Vol 36, No 10, p 519–527 (Dec 1955).

448. Stratton, J. A.

The Effect of Rain and Fog on the Propagation of Very Short Radio Waves
IRE Proc; Vol 18, No 6, p 1064–1075 (Jun 1930).

449. Sugiura, S.

Symposium on Synoptic and Radar Echo Analysis of Heavy Rain
Tenki; Vol 8, No 8, (1961).

450. Supiatskii, A. B.

Radar Scattering by Non-Spherical Particles
Tr Tsentr Aerolog Observ; No 30, p 39–52 (1959); Trans. by Kraus, D., Am. Meteorol. Soc., Boston, Mass., AD-414 331, Rep No TR 402, Contr AF 19(604)-6113 (Mar 1963).

451. Swingle, D. M.

The Effect of Attenuation on the Range Performance of Radar
Ill. State Water Surv., Urbana, Ill., Bull No 41, p 277–282 (1952).

Reviews the developments of meteorological instruments and states that the AN/CPS-9 set is specifically designed as a tool for the meteorologist in weather forecasting. The manner in which the operating wavelength was chosen is outlined, and the effect of attenuation due to various intensities of rain on the range of various types of equipment is analyzed.

452. Swisher, S. D.

Rainfall Patterns Associated with Instability Lines in New England
M.S. Thesis, Mass. Inst. of Tech., Cambridge, Mass. (Aug 1959).

453. Takahashi, Y.

Measurement of Rain Drop Size
Tenki to Kiko (title changed to Tenmon to Kisho); Vol 1, No 2, p 63 (1934).

454. Tex., Univ. of

Millimeter Wave Propagation
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-218 677, Semi-annual Sum Status Rep No 5, Contr Nonr-37501 (Jul 1959).

Deals with rain absorption measurements at 2.15 mm wavelengths and radio propagation measurements in the 100 to 118 kmcs spectrum. Describes an automatic rain dropsize distribution analyzer.

455. Tex., Univ. of

Research Activities in Millimeter Radiowaves and Geomagnetics
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-262 514, Rep No 124, Contr Nonr-37501 (Jul 1961).

456. Thuronyi, G.

Recent Literature on Radar Meteorology
Meteorol Abstr Bibliogr; Vol 9, No 8, p 1005–1030 (Aug 1958).

An annotated bibliography consisting of 130 items on radar meteorology is presented.

457. Tokunaga, K., Teramoto, S., Tanaka, T. and Kase, S.

Experimental Results of Microwave Attenuation Due to Rain along a Path
Electron Commun Japan; Vol 47, No 2, p 204–209 (1964).

458. Tolbert, C. W., Britt, C. O. and Straiton, A. W.

Apparent Temperature of Some Terrestrial Materials and the Sun at 4.3 mm Wavelengths
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., Rep No 93 (Jul 1957).

459. Tolbert, C.W. and Gerhardt, J.R.

Measured Rain Attenuation of 4.3 mm Wavelength Radio Signals
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-110 918, Rep No 83 (May 1956).

460. Tolbert, C.W., Gerhardt, J.R. and Bahn, W.W.

Rainfall Attenuation of 2.15 mm Radio Wavelengths
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-217 892, Rep No 109, Contr Nonr-37501 (Jun 1959).

The attenuation of 2.15 mm radio frequency energy by rainfall was measured and found to be in fair agreement with the attenuation calculated from the precipitation rates.

461. Tolbert, C.W. and Straiton, A.W.

Attenuation and Fluctuation of Millimeter Radio Waves
IRE National Convention Record; Vol 5, Pt 1, p 12–18 (1957).

462. Tolbert, C.W., Straiton, A.W. and Britt, C.O.

Propagation Studies between 18.0 and 25.5 kmcs
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-219 301, Rep No 110, Contr Nonr-37501 (Jul 1959).

Water vapor losses measurements made during propagation studies in the frequency spectrum of 18.0 to 25.5 kmc were found to have a maximum value of 0.0245 db/km/gram/m^3 near a frequency of 21 kmcs. Also observed was the possibility of a second maximum near 24 kmc.

463. Tolbert, C.W., Straiton, A.W. and Tipton, C.D.

Propagation Studies at 8.6-Millimeter Wavelength on 3.5-, 7- and 12-Mile Paths
Elec. Eng. Res. Lab., Univ. of Tex., Austin, Tex., AD-15 299, Rep No 69, Contr Nonr-37501 (Jun 1953).

Transmissions of the 8.6-mm waves over 3.5-, 7- and 12-mi. paths were within 3.5 db of the free-space value for 36 sets of measurements when rain did not occur. Large transmission losses resulted when showers occurred along the path. The losses were small during a fog.

464. Uda, H.

Radio Propagation in the Millimeter Wave Region
Denki Tsushin Gakkai, p 43–49 (1960).

465. Ugai, S. and Kaneda, Y.

Statistical Estimation of Microwave Attenuation due to Rain Cells
Rev Elec Commun Lab (Japan); Vol 11, No 5-6, p 268–283 (May–Jun 1963).

466. U.S.A.F. Climatic Center

Precipitation Attenuation at 8 kmc – Final Estimates
U.S.A.F. Climatic Center, Washington, D.C., Rep No 4100 (Feb 1962).

A study of path loss in a space communications system is presented.

467. U.S. Weather Bureau

Summary of Hourly Observations 1951–60 – Decennial Census of United States Climate
Climatography of the United States No 82, U.S. Govt. Printing Office, Washington, D.C. (1962–1963).

468. Usikov, O. Ya., Herman, V. L. and Vakser, I. Kh.

Investigation of the Absorption and Scattering of Millimetre Waves in Precipitations
Ukr Fiz Zh; Vol 6, No 5, p 618 – 641 (1961).

Experimental data are presented on the attenuation of radio waves (ranging in wavelength from 8.15 to 2.7 mm) in rain together with the basic results of a theoretical study of the absorption and scattering of millimetre radio waves in precipitations. Formulae are presented which permit one to calculate the absorption and scattering of millimetre radio waves, the distribution of raindrop size being known.

469. Van de Hulst, H. C.

Light Scattering by Small Particles
John Wiley & Sons, Inc., New York, 1957.

Includes material on scattering by precipitation particles.

470. Venugopal, V. R.

Meteorological Conditions and Radio Astronomy Observations at X-Band
J Atmos Sci; Vol 20, No 5, p 372 – 375 (Sep 1963).

Shows that the fluctuation component of atmospheric noise radiation is strongly correlated with cyclonic conditions and frontal activity.

471. Vogelhut, P. O.

The Dielectric Properties of Water and Their Role in Enzyme-Substrate Interactions
Elec. Res. Lab., Univ. of Calif., Berkeley, Calif., AD-401 670, Ser No 60, Issue No. 476, Contr Nonr-22292 (Aug 1962).

The structures of water, aqueous solutions, and ice are reviewed, primarily with regard to their electrical characteristics. A new cavity-perturbation measurement technique is used to obtain the dielectric constant of water and of aqueous solutions at microwave frequencies.

472. Von, V. M. H., Clark, R. A., Stephens, J. J. and Moyer, V. E.

Theoretical Investigation of the Applicability of a Dual-Frequency Radar System to the Study of Convective Liquid Precipitation
Dept. of Oceanogr. and Meteorol., Tex. A and M Univ., College Station, Tex., Sci Rep 63-22T, NSF Grant G-13834 (Sep 1963).

473. Von, V. M. H., Clark, R. A., Stephens, J. J. and Moyer, V. E.

An Investigation of Mie and Rayleigh Backscattering at 3.2 and 10.3 cm Wavelengths
J Geophys Res; Vol 69, No 16, p 2873 – 2880 (Jul 1964).

The ratio of Mie to Rayleigh scattering cross-sections can be represented by an eighth-degree polynomial for 3.2-cm radiation and by a second-degree polynomial for 10.3-cm radiation.

474. Voronets, V. M.

Methods of Radar Investigation of Precipitation
Tr El'brusskaya Vysokogornaya Ekspeditsiya; No 2(5), p 180 – 186 (1961); ATS-33P64R.

475. Voskresenskii, A. I. and Matveev, L. T.

Liquid-Water Content and Turbulent Regime of the Arctic Layering Clouds
Meteorol Gidrol; No 11, p 14 – 19 (1960); 63-19730.

476. Vul'fson, N. I. and Levin, L. M.

Interdepartmental Conference on Problems of the Investigation of Clouds, Precipitation, and Atmospheric-Electricity
Izv Akad Nauk SSSR, Ser Geofiz; No 6, p 735 – 739 (1956).

477. Walker, G. B., Lamberth, L. S. and Stephens, J. J.

Dual-Frequency Radar Observations of Precipitation
J Appl Meteorol; Vol 3, No 4, p 430 (Aug 1964).

An equal volume, dual-frequency radar system is used to obtain a quantitative characterization of a precipitation volume.

478. Weger, E.

Apparent Sky Temperatures in the Microwave Region
J Meteorol; Vol 17, No 2, p 159–165 (Apr 1960).

479. Weger, E.

Apparent Thermal Noise Temperatures in the Microwave Region
IRE Trans Antennas Propagation; Vol AP-8, No 2, p 213–217 (Mar 1960).

480. Wein, M.

The Electronic Correction for Attenuation of 3.2-cm Radar Signals from Rain
9th Weather Radar Conference, Kansas City, Mo. (Oct 1961), Sponsor: Am. Meteorol. Soc., p 367–370.

Radar signals at 3.2 cm have been corrected electronically for attenuation by rain before being displayed on a scale of gray. The signal from heavy cores is enhanced although the total area on the display remains that of the original attenuated signal.

481. Wexler, R.

Efficiency of Natural Rain
Am Geophys Union Geophys Monogr; No 5, p 158–163 (1960).

The efficiency of cloud in utilizing the water made available by the updraft for precipitation may be derived from a steady state equation involving storage and horizontal advection.

482. Wexler, R.

Particle Size Distribution in Rain and Snow Inferred from Z-R Relations
Blue Hill Meteorol. Observ., Milton, Mass.; Meteorol Radar Studies No 7, Contr AF 19(604)-950 (Dec 1957).

It is shown how the particle size distribution for rain or snow may be derived from the Z-R relation and the fall velocity relation.

483. Wexler, R.

Precipitation Growth in Stratiform Clouds
Quart J Roy Meteorol Soc; Vol 78, p 363–371 (Jul 1952).

The radar observations along the vertical of precipitation in stratiform clouds are compared with the theoretical growth rates of ice crystals in such clouds. The analysis indicates that no liquid water exists in these clouds at levels above about −5°C.

484. Wexler, R. and Atlas, D.

Factors Influencing Radar Echo Intensities in the Melting Layer
Quart J Roy Meteorol Soc; Vol 82, No 353, p 349–351 (Jul 1956).

485. Wexler, R. and Atlas, D.

Moisture Supply and Growth of Stratiform Precipitation
J Meteorol; Vol 15, No 6, p 531–538 (Dec 1958).

The steady-state water-budget theory is developed for stratiform precipitation.

486. Wexler, R. and Atlas, D.

Radar Reflectivity and Attenuation of Rain
J Appl Meteorol; Vol 2, No 2, p 276–280 (Apr 1963).

487. Wexler, R. and Austin, P. M.

Radar Signal Intensity from Different Levels in Steady Snow
Weather Radar Res., Mass. Inst. of Tech., Cambridge, Mass., AD-63 866, Res Rep No 23, Contr DA 36-039-sc-42625 (Mar 1954).

488. Wexler, R. and Boucher, R. J.

Radar Echoes from a Growing Thunderstorm
Mt. Washington Observ., Gorham, N. H., AD-145 298, Prog Rep Nos 5-6, Contr AF 19(122)-399 (Oct 1951-Apr 1952).

Describes vapor density differences between a growing ice crystal and its environment and gives the results of cloud droplet impinger measurements.

489. Wexler, R. and Boucher, R. J.

Theoretical Studies Related to the Growth of Precipitation Particles, and Empirical Studies and Statistical Analyses of Particle Size Distributions in Rain and Clouds and Their Relationship to Radar Reflectivity
Mt. Washington Observ., Gorham, N. H., Final Rep, Contr AF 19(122)-399 (Jul 1952).

The subjects covered are: the effect of coalescence on drop size distribution, radar echoes from thunderstorms, heat balance of growing ice particles, nylon screen for measuring drop size distribution and liquid water content.

490. Wexler, R. and Weinstein, J.

Rainfall Intensities and Attenuation of Centimeter Electromagnetic Waves
IRE Proc; Vol 36, No 3, p 353–355 (Mar 1948).

Analyzes the rain frequency and intensity from four stations in the United States and makes an areal study to determine the rain attenuation of an X-band radar.

491. Whalley, H. and Scoles, C. J.

Radar Observation of Heavy Rain
Nature; Vol 163, No 4140, p 372 (Mar 1949).

Describes a belt of rain 50 miles wide passing over Manchester, Nov. 19, 1948. Illustrations are included.

492. Wilk, K. E.

Radar Investigations of Illinois Hailstorms
Ill. State Water Surv., Urbana, Ill., AD-252 198, Sci Rep No 1, Contr AF 19(604)-4940 (Jan 1961).

The use of radar in the detection and identification of severe thunderstorms was considered.

493. Zaitsev, V. A.

Water Content and Droplet Distribution in Cumulus Clouds
Tr Gl Geofiz Observ; No 19, p 122–132 (1950).

494. Zak, Ye. G. and Federova, A. A.

Some Results of Radio-Location Observations on the Formation and Development of Precipitation in Shower Clouds
Tr Tsentr Aerolog Observ; No 19, p 33–67 (1958); 61-13093.

The aim of these observations was the study of the character of the radio-echo obtained from convective clouds, and the discovery of the features of the reflections connected with the development of shower clouds in different synoptic-aerological conditions. The observations were carried out with a "Cobalt" 3.2-cm radio-locator.

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13. ABSTRACT

This bibliography is offered to encourage the further application of radar meteorological techniques and data in connection with the study of the effects of hydrometeors, precipitation, clouds and fog on microwave propagation. It combines material developed in regard to weather radar research with the more conventional works on attenuation. In addition to the weather radar material, the bibliography includes references on thermal radiation from precipitation, cloud physics, and dielectric and scattering properties of hydrometeors. Some of the references are pertinent to the study of propagation at optical wavelengths and are useful in evaluating the performance of laser communications systems.

14. KEY WORDS

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